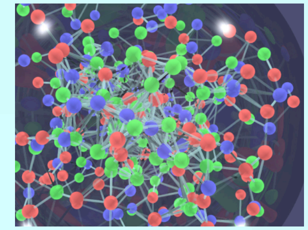
PHENIX Operations: performance & plans

- PHENIX mission, productivity, science impact
- Operational Efficiency
  - In Run-10
  - Future further improvements
- Detector Improvements
  - For the next ~3 years
  - Decadal Planning progress
- RHIC resource management

Barbara Jacak. Special thanks to Stefan Bathe (Run-10 Coordinator), Jamie Nagle (Decadal Plan Chair)

http://www.phenix.bnl.gov/WWW/publish/jacak/sp/presentations/BeamUse10/BUP10.pdf

PHENIX mission



- *Reseach* and *Education* (Ph.D. and M.S.)
- Overarching physics goals
  - Establish nature of RHIC's new state of matter
    - sensitive, rare probes: di-leptons, heavy flavor, jets
  - Understand the spin of the proton:
    - g, $\bar{q}$ polarization & parton/nucleon spin correlation
- PHENIX approach
  - Rare process sensitivity
  - High rate capability + selective triggers
  - Precision measurement in multiple channels
  - Continuously upgrade capabilities
- *Challenge: Keep up data analysis in parallel with:*
  - *Data taking, Constructing upgrades*
  - *Writing high impact papers (900 citations of White paper, 1 other topcite 500+, 5 250+, 20 topcite 100+, 29 50+, and 2 with 49 citations)*

PHENIX Detector

Central Arm Tracking
- Drift Chamber
- Pad Chambers
- Time Expansion Ch

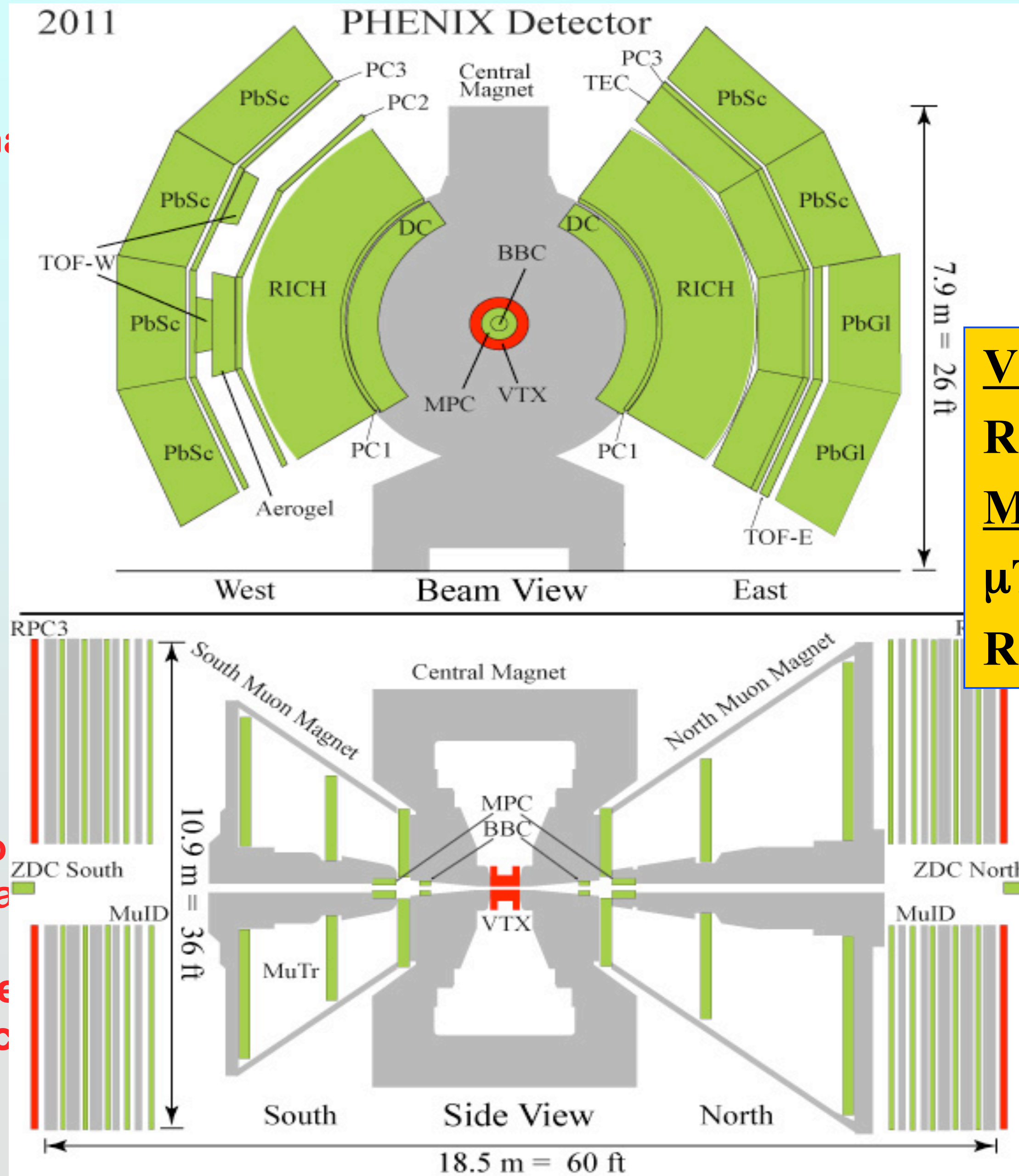
Muon Arm Tracking
- Muon Tracker

Calorimetry
- PbGl
- PbSc
- MPC

Particle Id
- Muon Identifier
- RICH, HBD
- TOF E & W
- Aerogel
- TEC

Global Detectors
- BBC
- ZDC/SMD Local Po
- Forward Hadron Ca
- RXNP

DAQ and Trigger Syste
Online Calib. & Produc



<u>VTX</u>
Replaces HBD
<u>Muon Trigger:</u>
μTr FEE
RPC station 3

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Myongji University, Yongin, Kyonggido 449-728, Korea
System Electronics Laboratory, Seoul National University, Seoul, South Korea
Yonsei University, IPAP, Seoul 120-749, Korea
IHEP Protvino, State Research Center of Russian Federation, Institute for High Energy Physics,
Protvino, 142281, Russia
Joint Institute for Nuclear Research, 141980 Dubna, Moscow Region, Russia
Russian Research Center "Kurchatov Institute", Moscow, Russia
PNPI, Petersburg Nuclear Physics Institute, Gatchina, Leningrad region, 188300, Russia
Saint Petersburg State Polytechnic University, St. Petersburg, Russia
Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Vorob'evy Gory,
Moscow 119992, Russia
Department of Physics, Lund University, Box 118, SE-221 00 Lund, Sweden

PHENIX 14 Countries; 70 Institutions

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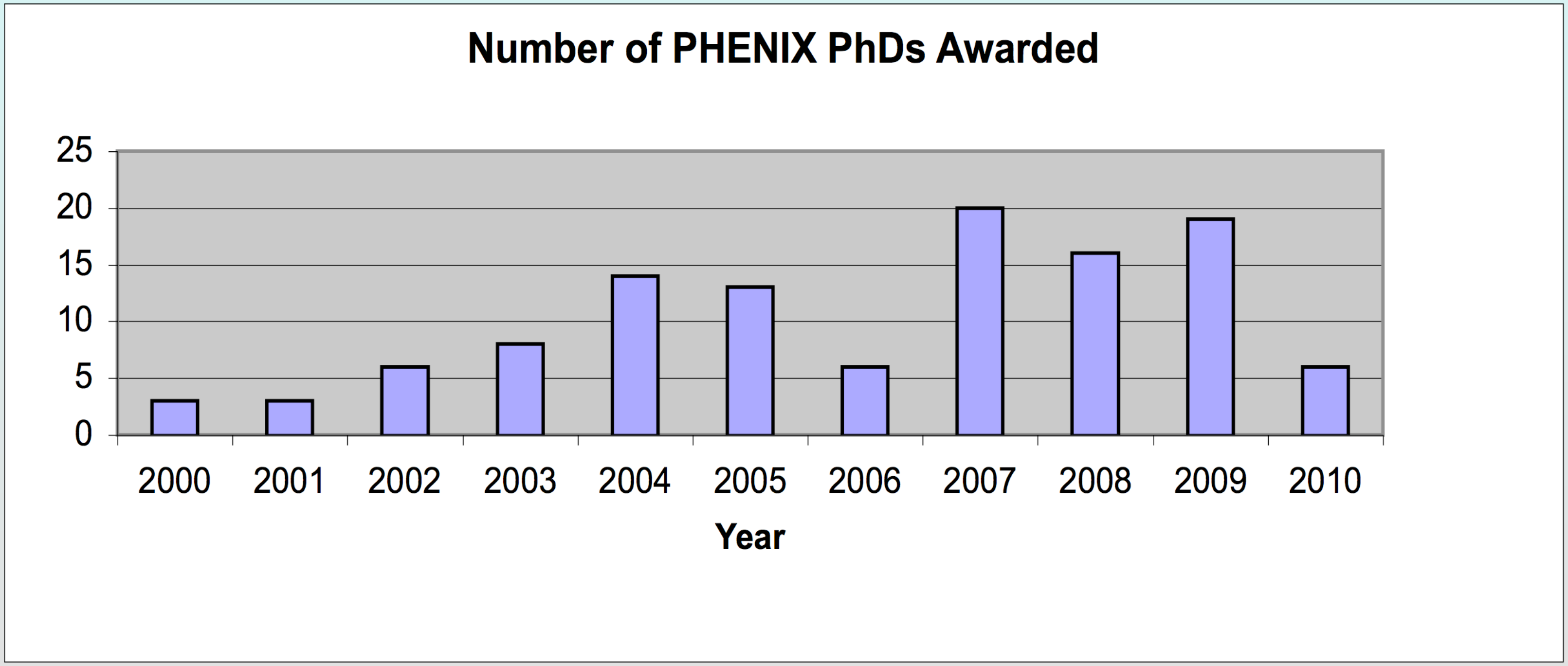
University of Tennessee, Knoxville, TN 37996, U.S.
Vanderbilt University, Nashville, TN 37235, U.S.

PHENIX is very educational!

- 104 Ph.D's granted, to date
- 24 Masters' degrees
- >90 students currently working on PHENIX



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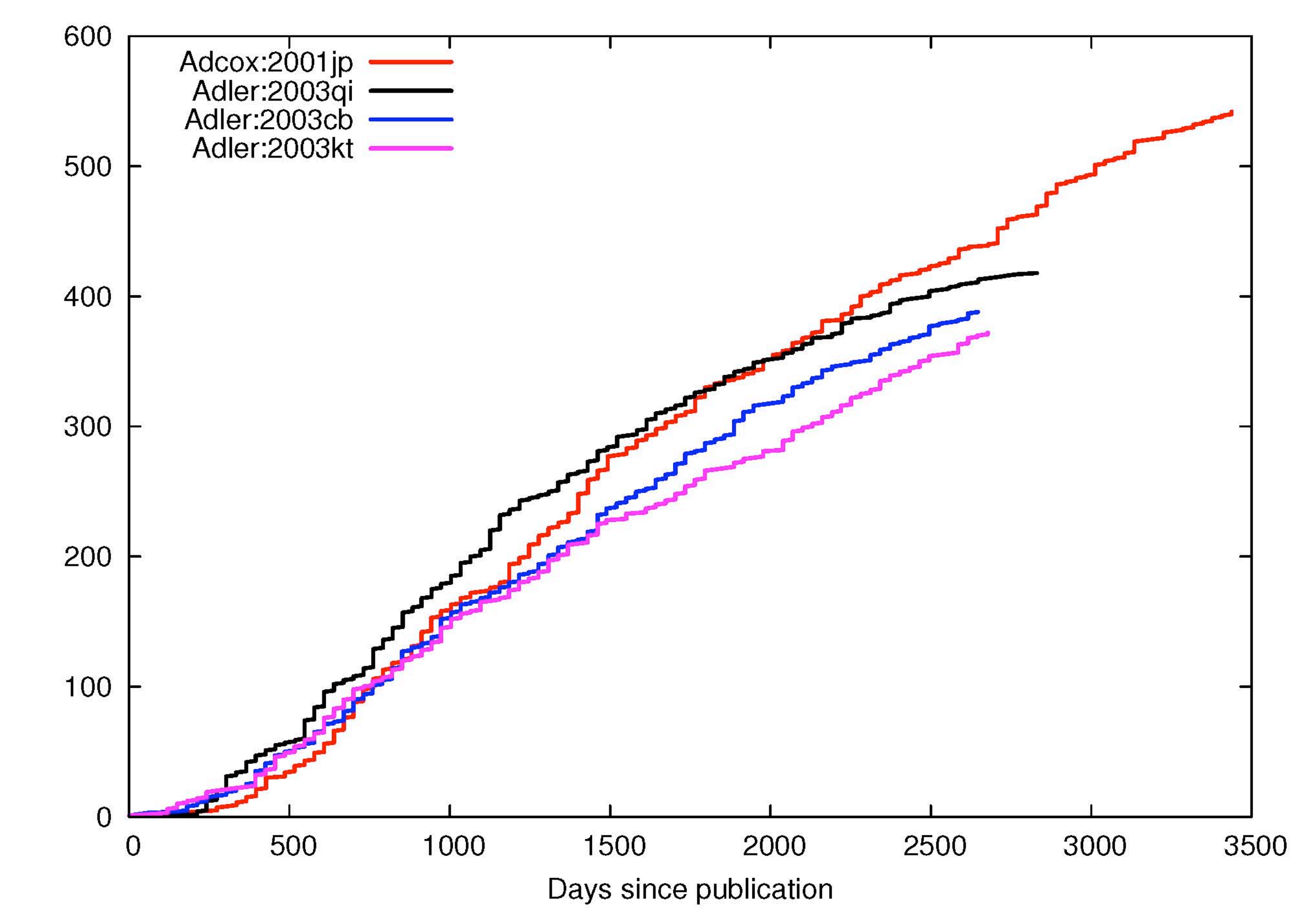
Recent exciting scientific accomplishments

- **Thermal radiation at RHIC** *PRL 104, 132301 (2009)*
- **Di-electrons in Au+Au & p+p** *PRC81, 034911 (2010)*
- **heavy flavor R_{AA} and v_2** *1005.1627*
- **γ-h and h-h correlations** *1006.1347, 1002.1077*
- **J/ψ polarization** *0912.2082*
- **η, ϕ suppression** *1005.4916, 1004.3532*
- **high p_T π^0 v_2** *PRC80, 054907 (2009), 1006.3740*
- **Meson systematics in p+p** *1005.3674*
- **Charged hadron v_4, v_2** *1003.5586*
- **Helicity sorted jet k_T** *PRD81, 012002 (2010)*

Just how exciting? Scientific impact…

- 88 papers published, 51 of them PRL's (!)
- + one paper in proof, 7 in referee process
- PHENIX White Paper has 900 citations!
- 3 major archival papers within the last 12 months



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High visibility for hottest matter on earth!

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DISCOVER
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Physics & Math / Subatomic Particles

The Hottest Science Experiment on the Planet

In a Long Island lab, gold particles collide to form a subatomic stew far hotter than the sun.

by Calla Cofield
published online February 15, 2010

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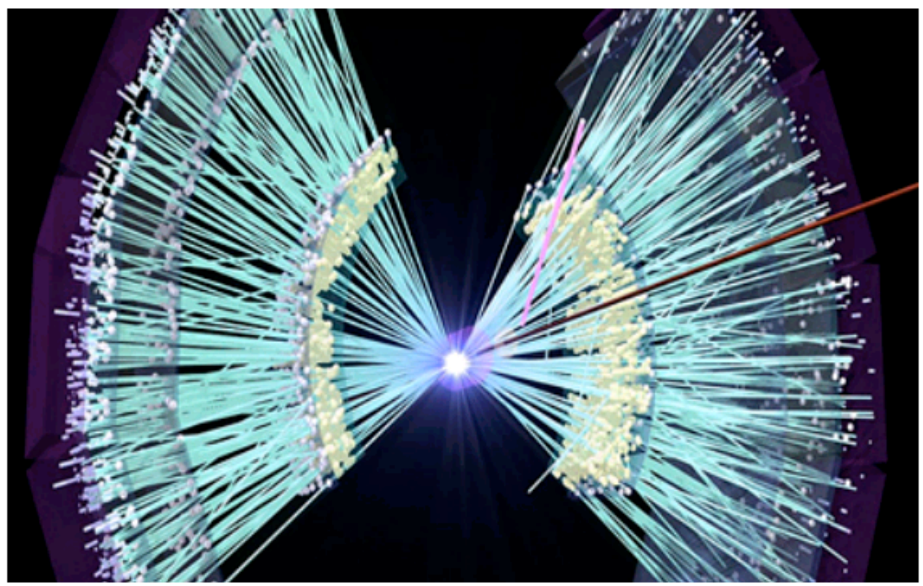
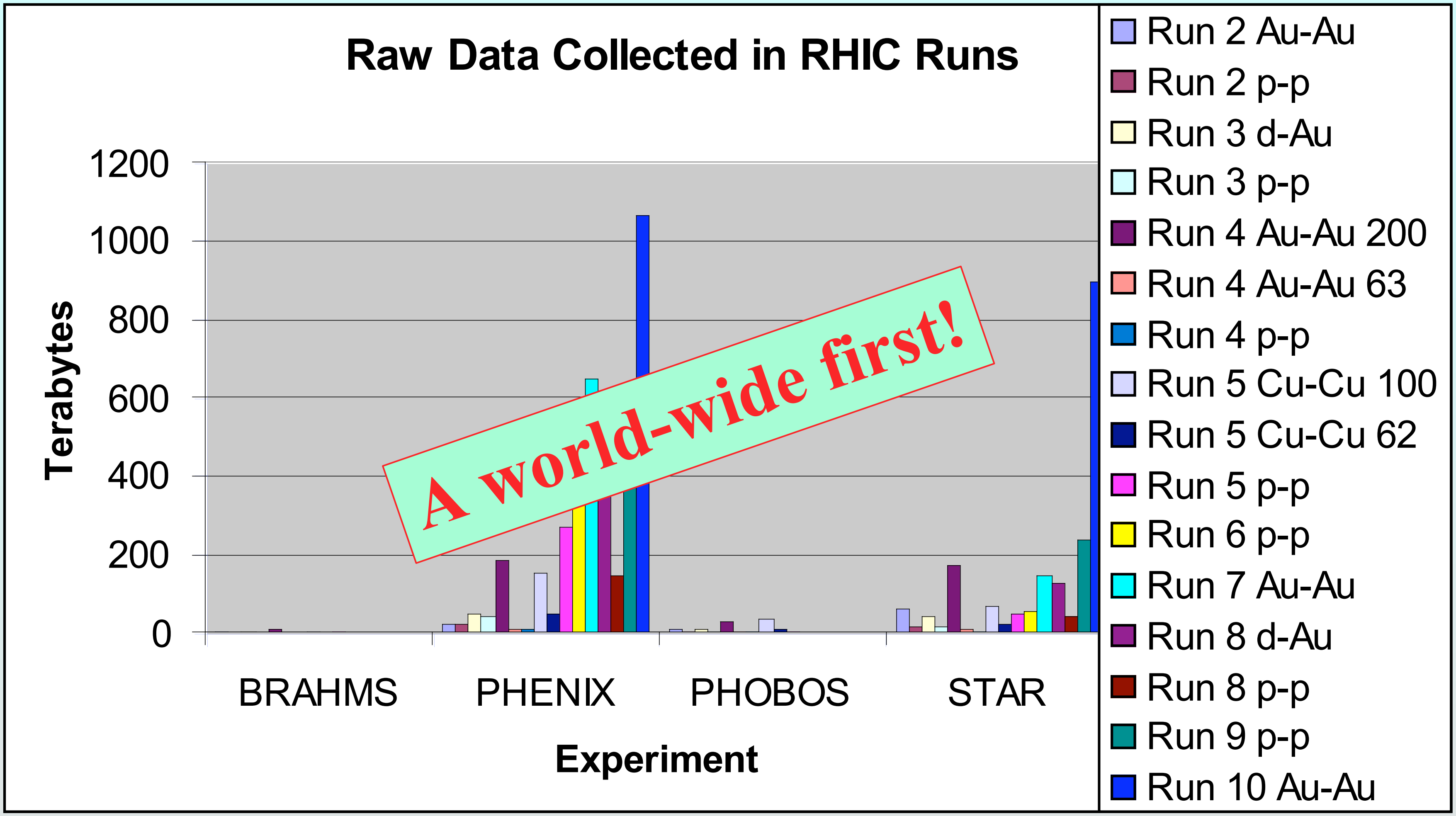
Rocking the thermometer at 4 trillion degrees Celsius, a subatomic soup that might reflect the state of matter shortly after the Big Bang has set a new world record: It's the hottest substance ever created in a lab. The previous record, recorded at Sandia National Lab in 2006, was a balmy 2 billion degrees Celsius. The core of the sun burns at a chill 15 million degrees.

The uber-hot brew is created at Brookhaven National Laboratory on Long Island. The lab's Relativistic



Milestone! PHENIX data rate >1 PB/year



Production teams drawn from the collaboration

Run-10: Jeff Mitchell (BNL), Nathan Grau (Columbia), Darren McGlinchey (FSU)

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PHENIX Operations in Run-10

Superb RHIC performance → lots of data

Table 1: PHENIX Data Sets in Run-10

SPECIES	$\sqrt{s_{NN}}$	Requested	Recorded	Recorded (events)
Au+Au	200	1.4 nb^{-1}	1.3 nb^{-1}	8.2G
Au+Au	62.4	350M events	0.11 nb^{-1}	700M
Au+Au	39	50M events	40 μb^{-1}	250M
Au+Au	7.7		0.26 μb^{-1}	1.6M

larger than expected data sets → additional observables

J/ψ suppression at 62.4 GeV to test recombination

low mass e+e- excess; π/K/p flow at 39 GeV

hadron yields, ratios, spectra, fluctuations

& correlations at √ s = 7.7 GeV

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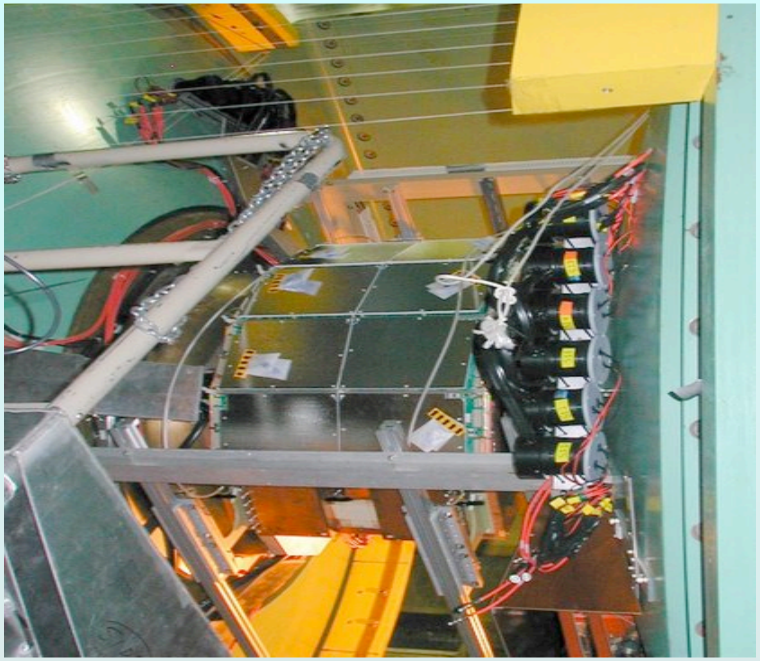
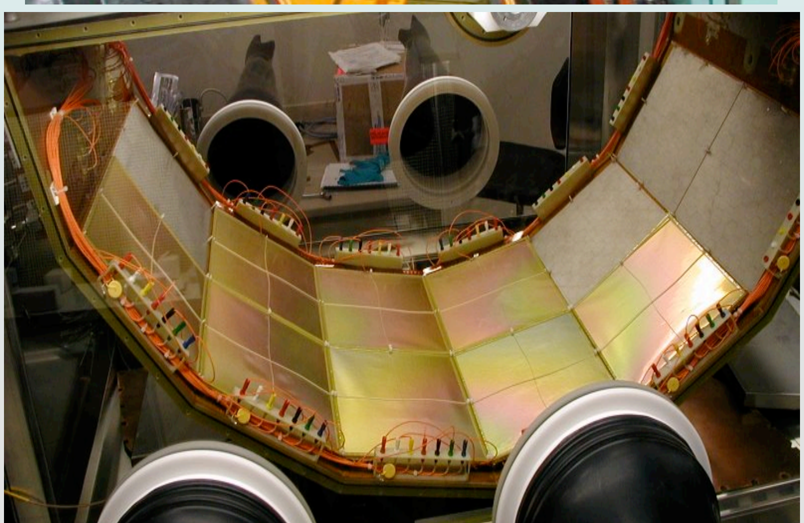
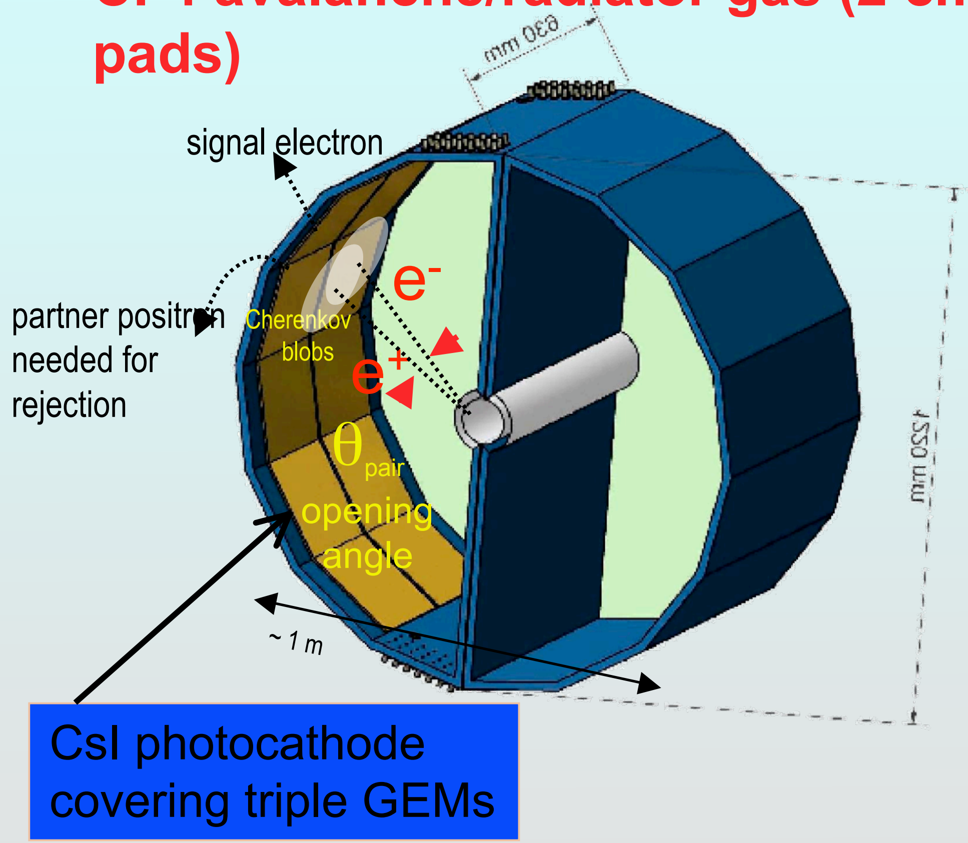
Run-10 focus: Hadron Blind Detector





Windowless Cerenkov detector with CF4 avalanche/radiator gas (2 cm pads)



Removes Dalitz & conversion e^+e^- background (small opening angle)

HBD response in Au+Au as in Run-9 p+p

From initial analysis of peripheral Au+Au events

Expect good separation of signal & background!

Background suppression: effective $\sigma_{statistical}$ improves by ~6

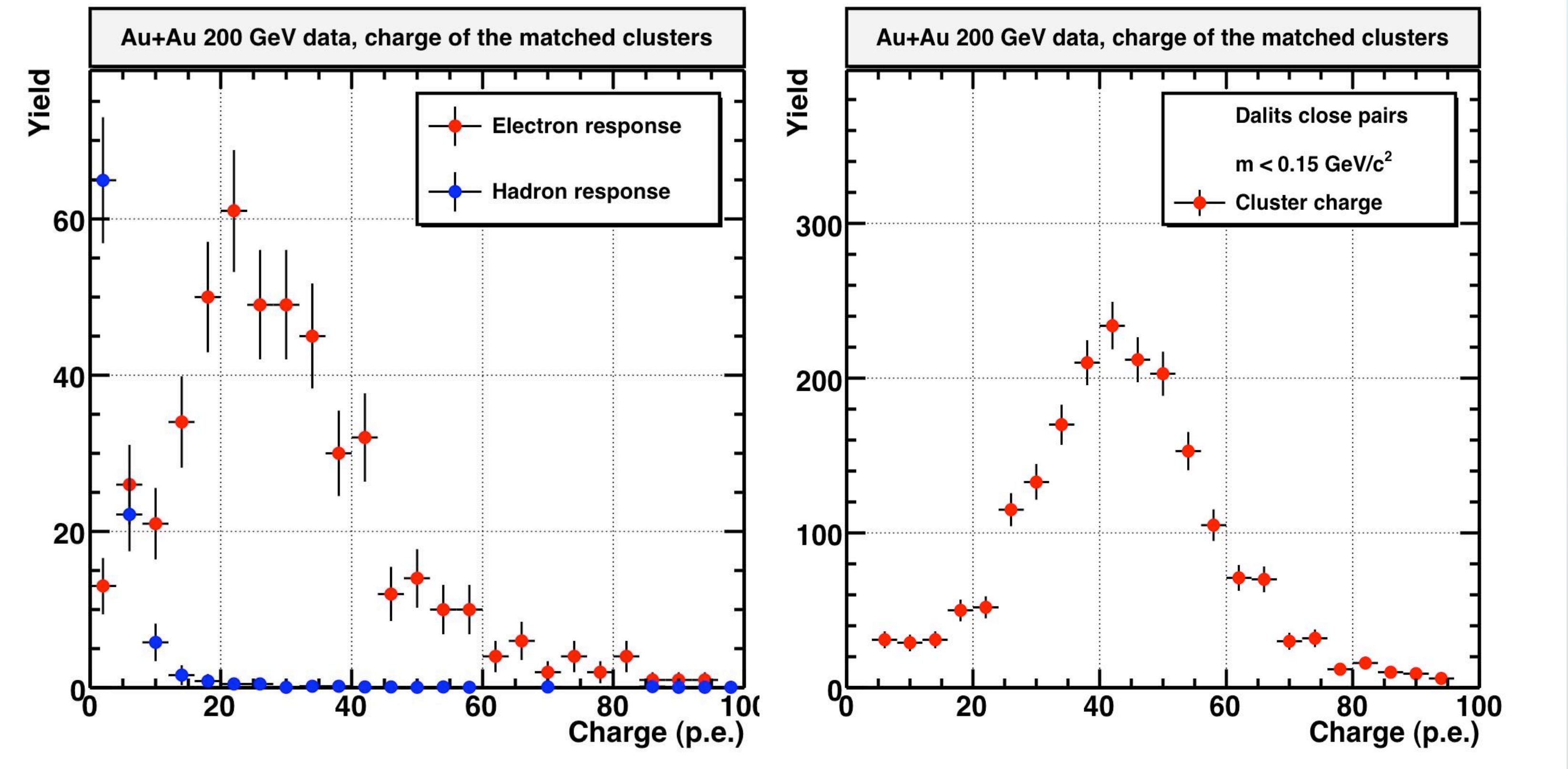
Signal (separated electrons):

~ 20 photo-electrons

2 e backgrd (Dalitz, conversion):

40 photo-electrons

hadron: few pe



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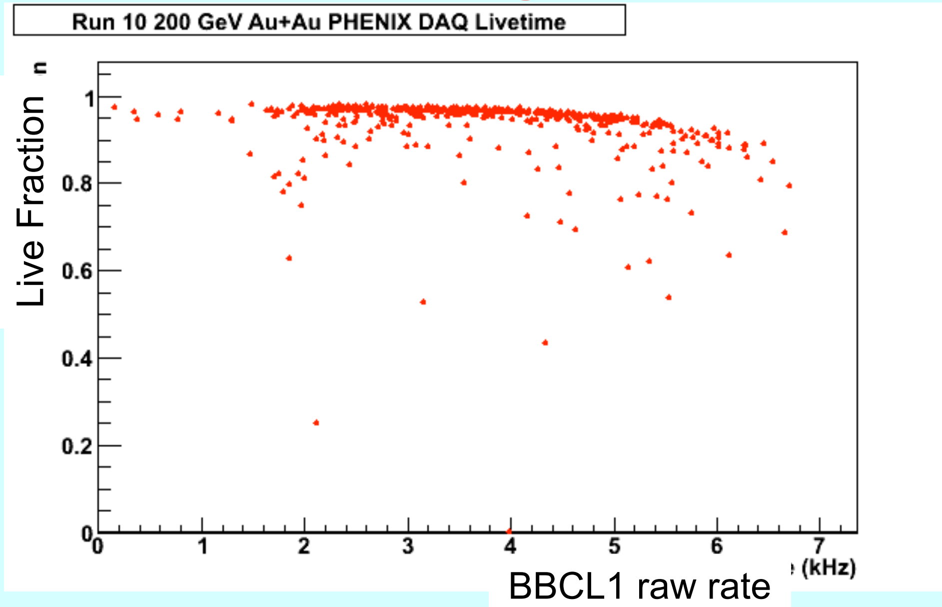
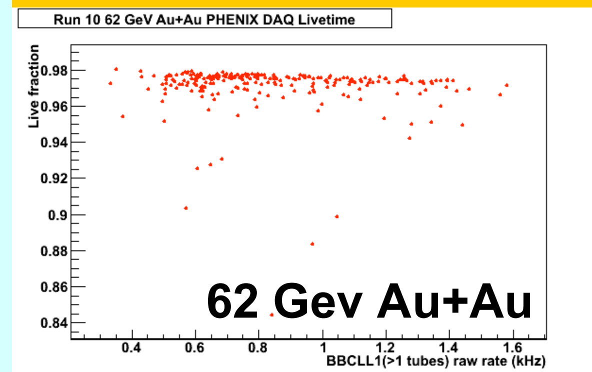
Operational changes for Run-10

- **DAQ livetime 90 → 95% up to 5.5 kHz**

  Prescale configurations make optimal use of livetime



DAQ livetime > 95 %
at up to 5.5 kHz
raw event rate



- **Introduced different vertex cuts at trigger level 1**

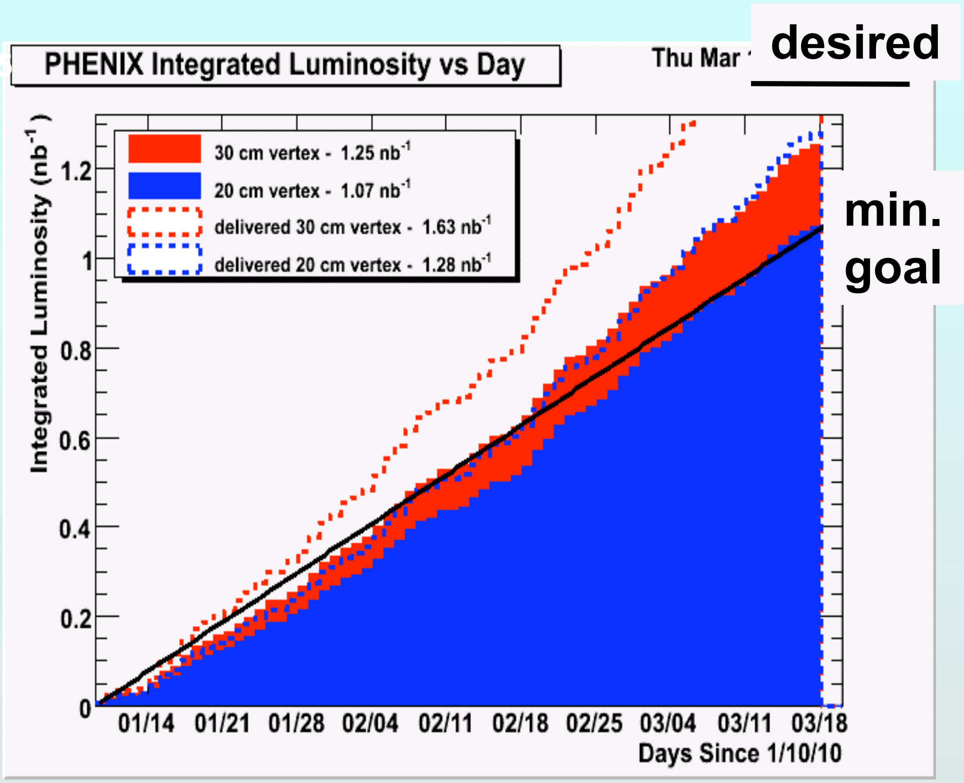
  Key for future running with VTX + muon arms

  Allowed to maximize *useful* events in HBD

- **CAD's new LLRF removed need to switch between RHIC and internal clock during filling. → 10 min fills at low √ s, end of "clock glitches" & DAQ element re-synch**

  will increase uptime in Run-11 onward

200 GeV Au+Au: Jan 10 - Mar 18, 2010

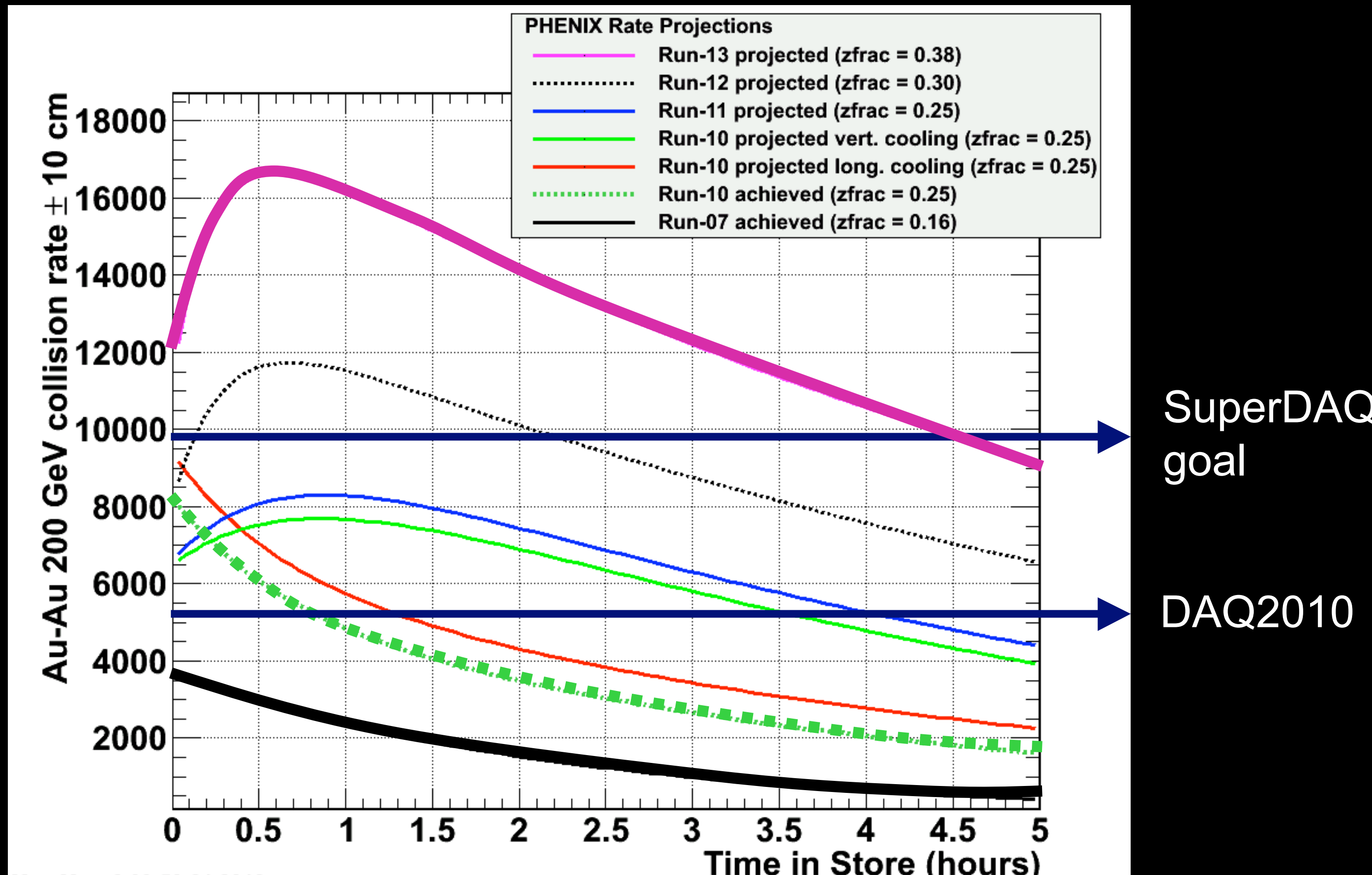


Goal reached. Success!

- Run-10 data set factor 1.5 larger than Run-7 data and has functioning HBD!

- Our goal was to
  record 1.4 nb^{-1} (± 30 cm)
  Expectation: 1.1 nb^{-1} in ± 30 cm in 10 weeks
- Recorded
  8.2 B MB events
  1.3 nb^{-1} into ±30 cm vx
  7.0 B MB events
  1.1 nb^{-1} into ± 20 cm
- Sampled 1.35 nb^{-1} (rare trigger test: ready for Run-11)
- **We got**
  86 % of all MB in ±20 cm
  77 % of all MB in ±30 cm

CAD Projections



RHIC II luminosity and new proposed DAQ upgrades can sample 50 billion AuAu events, including recording ~25 billion minimum bias events (i.e. no trigger bias).

Thanks to Wolfram Fischer and CAD for input.

Definitions:

- ***Vertex cut***

  Inside +/- 30 cm longitudinally (50% of luminosity)
- **Livetime**

  DAQ is not busy - ready for events (traditional definition)
- ***DAQ efficiency***

  Fraction of delivered luminosity within vertex cut sampled by the PHENIX Level-1 triggers when the DAQ is running (includes livetime and trigger prescale factors)

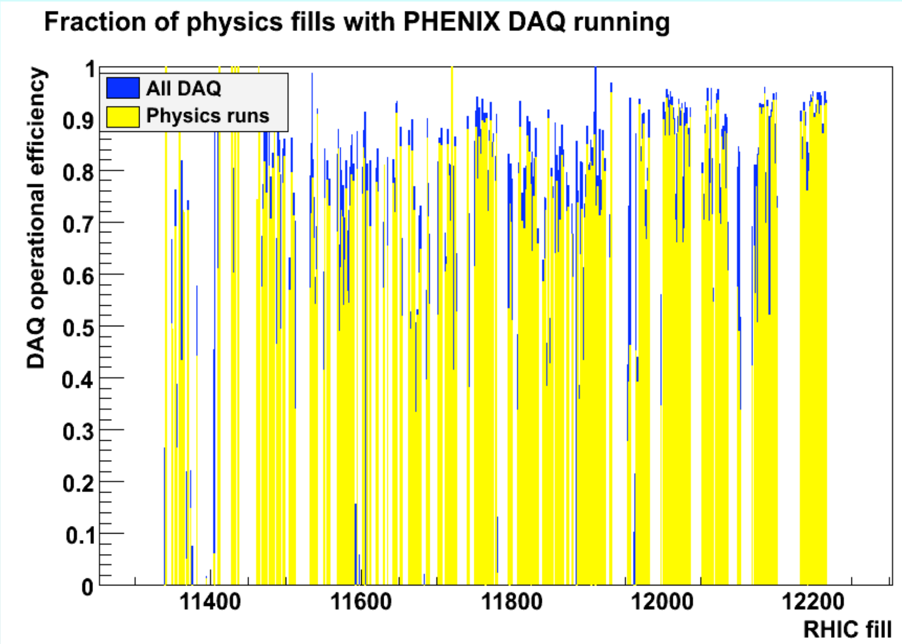
  Time when DAQ rate is saturated contributes here
- ***PHENIX Uptime***

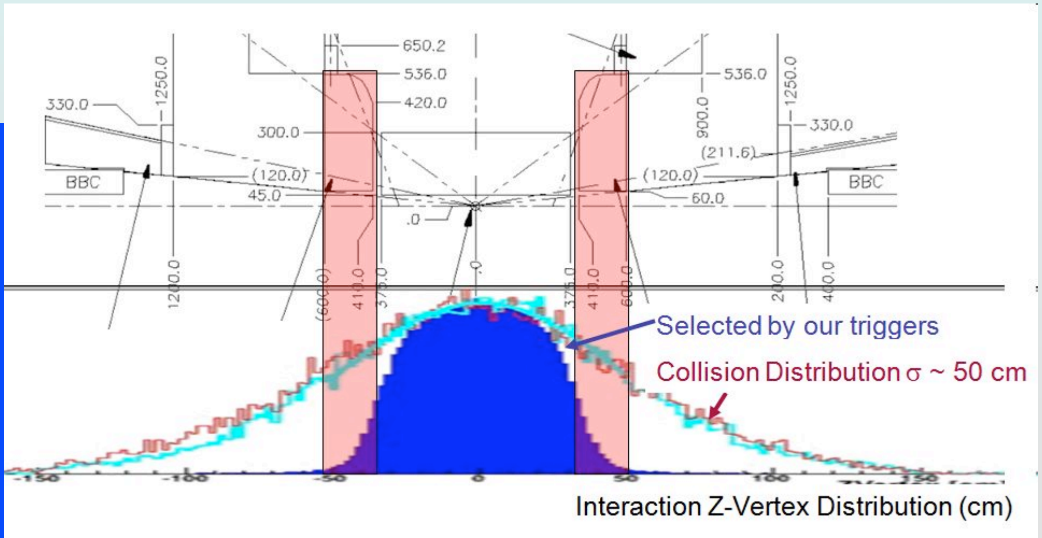
  Fraction of delivered “cogged/steered/collimated” luminosity when the PHENIX detector and DAQ are taking *good* data

  Contributing factors: HV ramp, integration/set-up work, non-physics data (calibrations, field-off or problem runs)
- **PHENIX efficiency = DAQ efficiency x uptime**

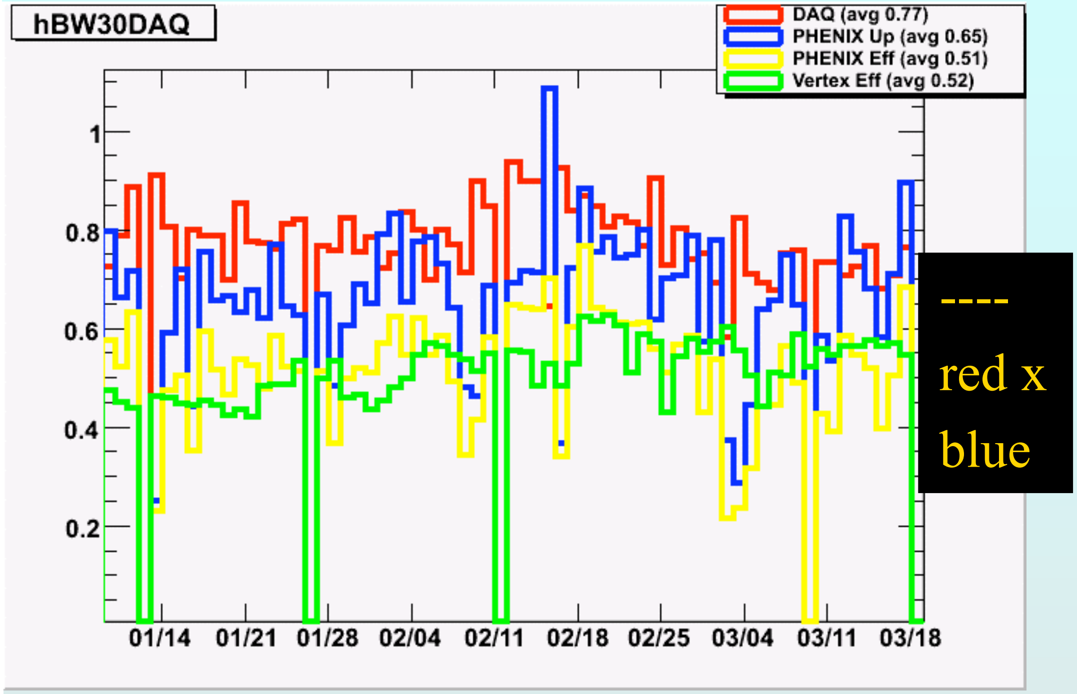
Detector Operations in Run 10

- Maximize uptime: excellent Run Coordinator (Stefan Bathe) leading tiered management.
- 5 person shift crews, bi-weekly Period Coordinators, on-call DAQ & detector experts; daily shift-change meetings
- Statistics logged at many places (scalers, network speeds, etc.) and monitored
- L1 selection on longitudinal vertex optimizes events for offline analysis
- Normally ~50% inside ±30 cm, beam can spread out or develop side-lobes which reduce that





PHENIX and RHIC luminosity increase



- Collision rate vs. Run-7:
  X2 at 0.5 hour
  X2.35 at 2 hours
- Improvements allow DAQ to ~keep up with RHIC
- DAQ "eff" decrease only from 82% to 77%*
- PHENIX collected data set x1.5 in 75% run length

Year	2007	2007 (last 2 wks)	2008	2008	2010
Species	Au+Au	Au+Au	d+Au	p+p	Au+Au
Uptime	64%**	72%	77%	69%	66%***

Uptime dominated by HV ramp after beam backgrounds are "safe"

**detector commissioning ***strict definition of Physics Run

* In Run-10: 92% rate-ave livetime, 84% of *all* events sampled/record

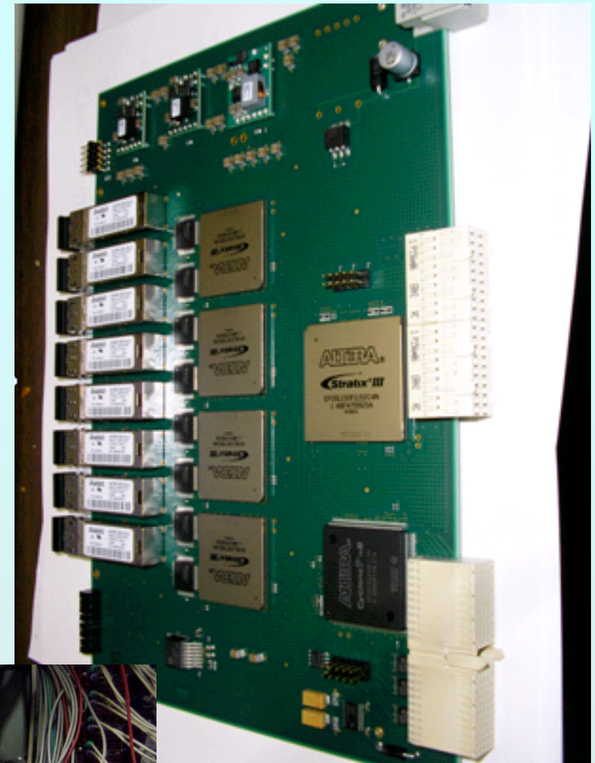
→ 1.35 nb^{-1} sampled by all triggers, 1.3 nb^{-1} MB recorded

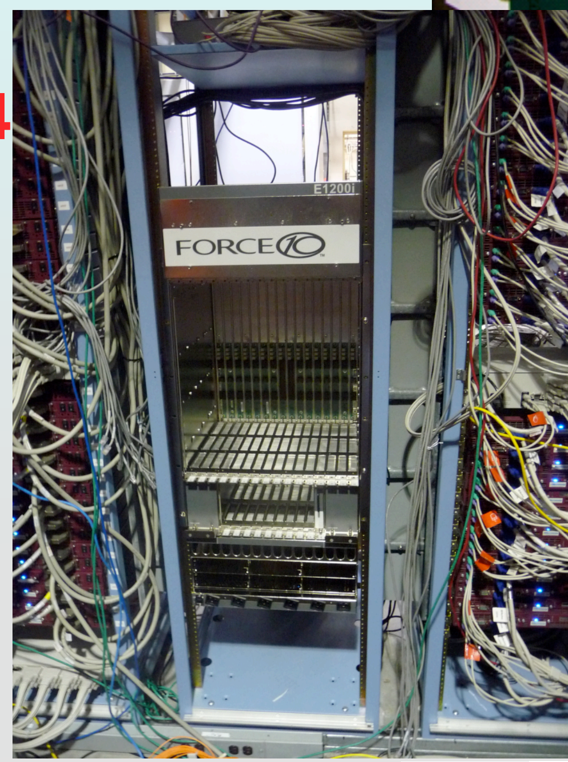
sDAQ

- SuperDAQ upgrade
- aggressive goal!
- performance will be known in Run-11

- Switch to all DCM II
  Cost is $700k-$1M
  Time scale 2012-2014

- New switch is here, part of DAQ2010
- Also part of DAQ2010
  New SEB, JSEBII
  Test set this year





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PHENIX Upgrades: short/medium term

Run-9 & Run-10:
Hadron Blind Detector. Low mass dileptons to probe early dynamics

Run-11:
Silicon VTX on schedule. Precision Heavy Flavor - c vs. b energy loss to probe strong coupling effects in plasma

Muon Trigger Upgrade on schedule. Forward $W \rightarrow \mu$ to probe $q,\bar{q}$ spin
DAQ2010 Upgrade on schedule. Increased data volume, trigger rejection

Run-12:
Forward Silicon VTX available. Precision Heavy Flavor at higher η

Run-14:
* Forward Calorimetry (potential proposal) Gluon Saturation Physics

*SuperDAQ Upgrade goal is to double the AuAu rate

Maintenance is key for aging detectors!

→ Continuing need for operating capital equipment $

PHENIX

R&D & Capital impact on PHENIX

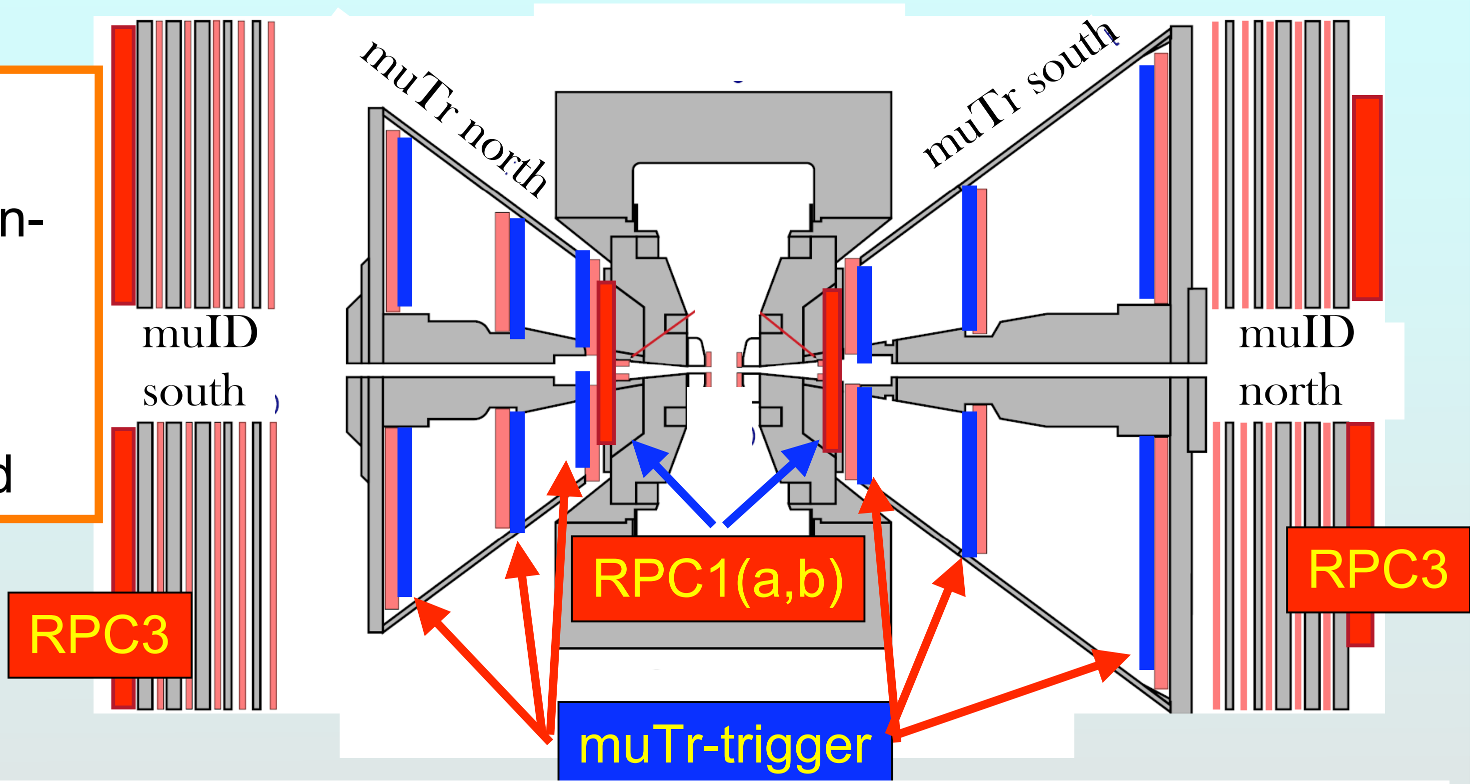
- Key R&D projects prior to construction:
  HBD, VTX, FVTX, MuTrigger
  R&D allowed developing new technologies
  HBD: $680K, VTX $900K, FVTX $240K + $3M LANL LDRD
  MuTRG: $160K
  NB: construction funds from RIKEN & NSF
- DAQTRIG2010 has improved efficiency already!
  Work is underway on trigger rejection & DAQ rate
  $900K R&D (includes DCMII & EMCAL trig), $300K cap
- Other infrastructure from ops capital: beampipe, racks, platforms, access, background shielding
- Compact calorimetry
  $360K R&D from 2008-2010, including beam tests
  develop technology for FOCAL and central barrel
  $100K R&D in 2010 for compact EM barrel/tracker

Muon Trigger Upgrade

Trigger idea:

Reject low momentum muons

Cut out-of-time beam background



Upgrade:

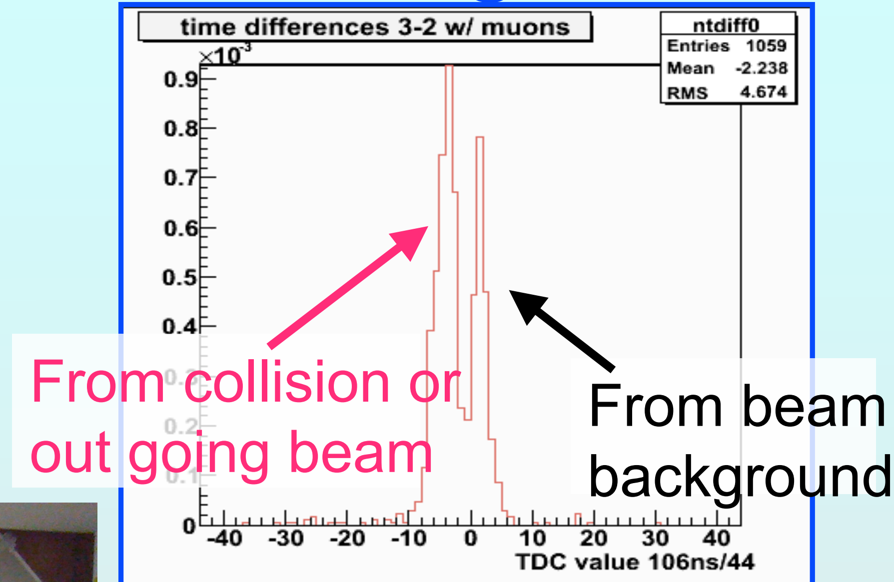
o muTr trigger electronics: muTr 1-3 ➔ send tracking info to level-1 trigger

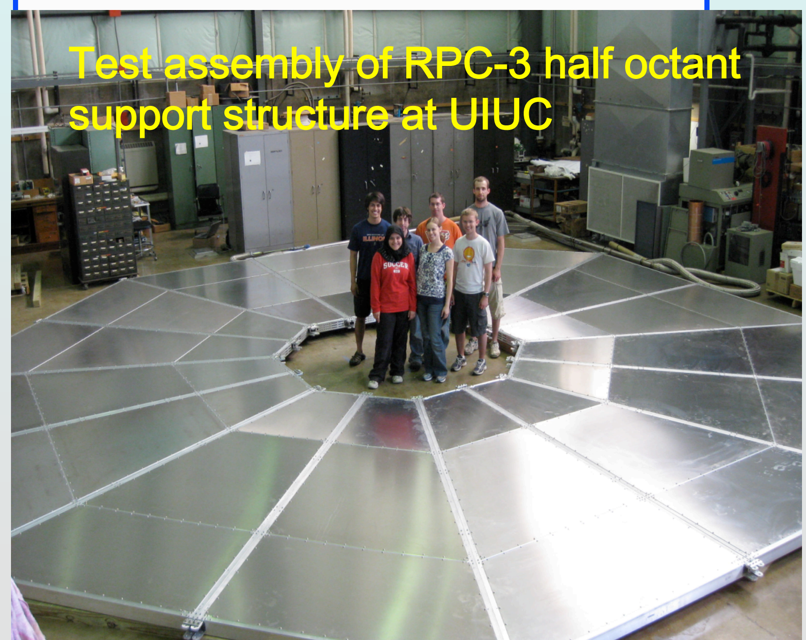
o RPC stations: RPC 1+3 ➔ tracking + timing info to level-1 trigger

note: RPC1 has larger acceptance than RPC3 at large radii,
RPC1+ RPC3 give best coverage for timing needed for background rejection.

RPCs: trigger level timing

- Timing used in Run-9 to characterize background
- RPC3-N installed for Run-10
- Commissioned & ready



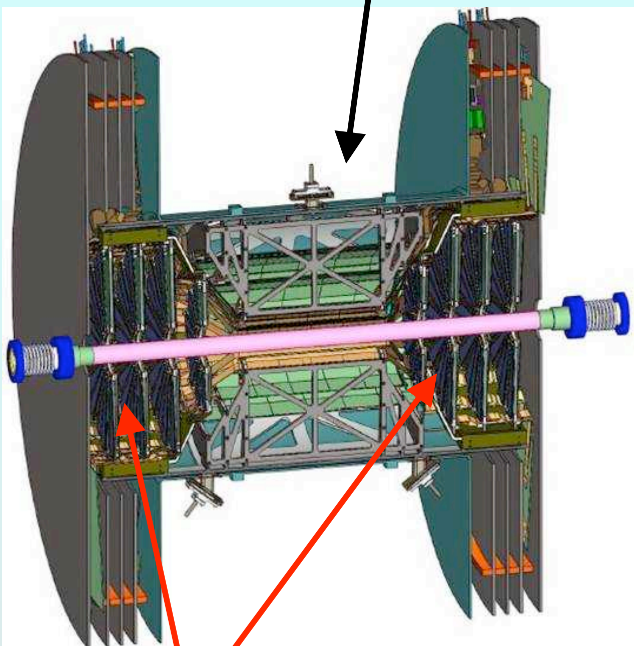


Silicon Vertex (VTX & FVTX)

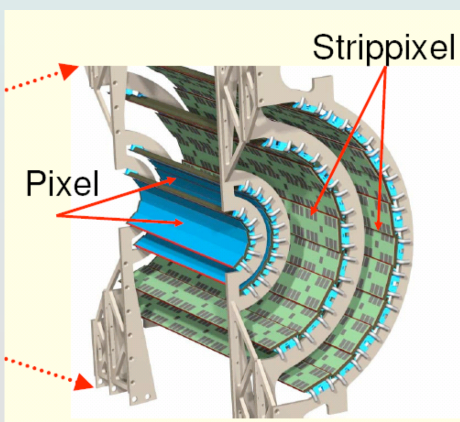
Q: does QGP stop b quarks too?

→ interaction & coupling strength

VTX barrel $|\eta|<1.2$



FVTX
endcaps
$1.2<|\eta|<2.7$
mini strips



VTX

Fine granularity, low occupancy
- **50μm×425μm pixels for L1 and L2**
- **R1=2.5cm and R2=5cm**

Stripixel detector for L3 and L4
- **80μm×1000μm pixel pitch**
- **R3=10cm and R4=14cm**

Large acceptance
- **$|\eta|<1.2$, almost 2π in ϕ plane**

Displaced vertex, standalone tracking

Install for Run-11

FVTX: Forward si VerTeX tracker
- **2 endcaps with 4 disks each**
- **pixel pad structure (75μm x 2.8 to 11.2 mm)**

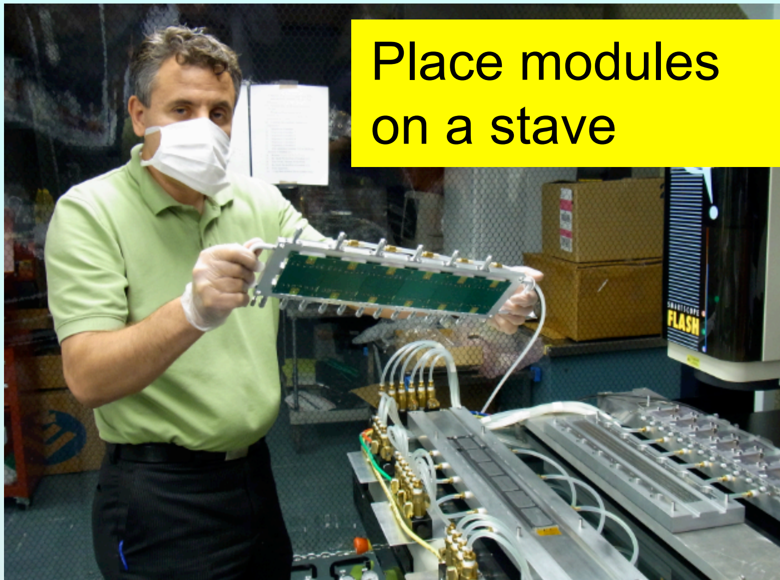
Displaced vertex tag, μ p resolution

Install for Run-12

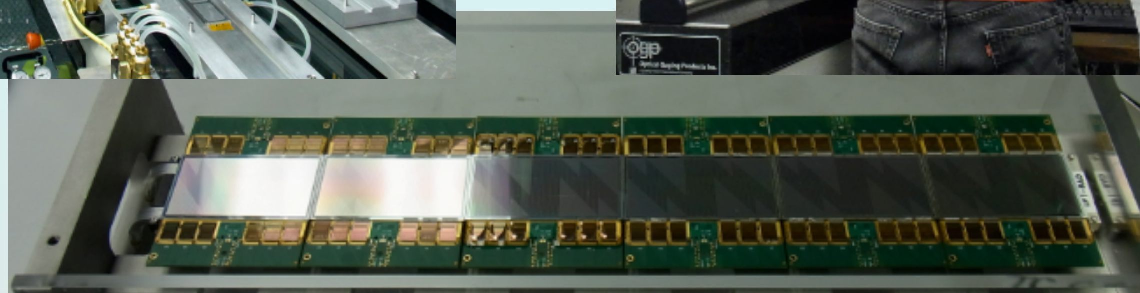
PHENIX

VTX : Strips on track to complete by RUN11

Place modules on a stave

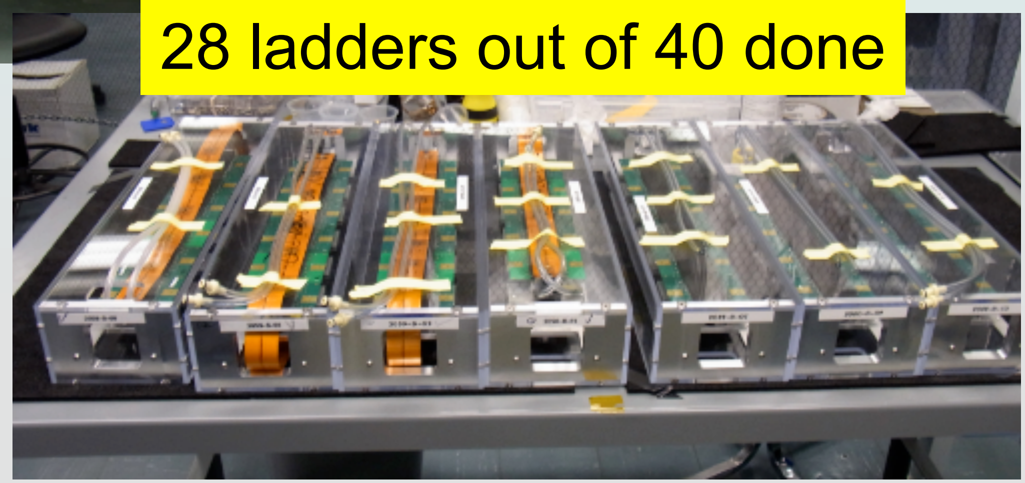


Align the modules



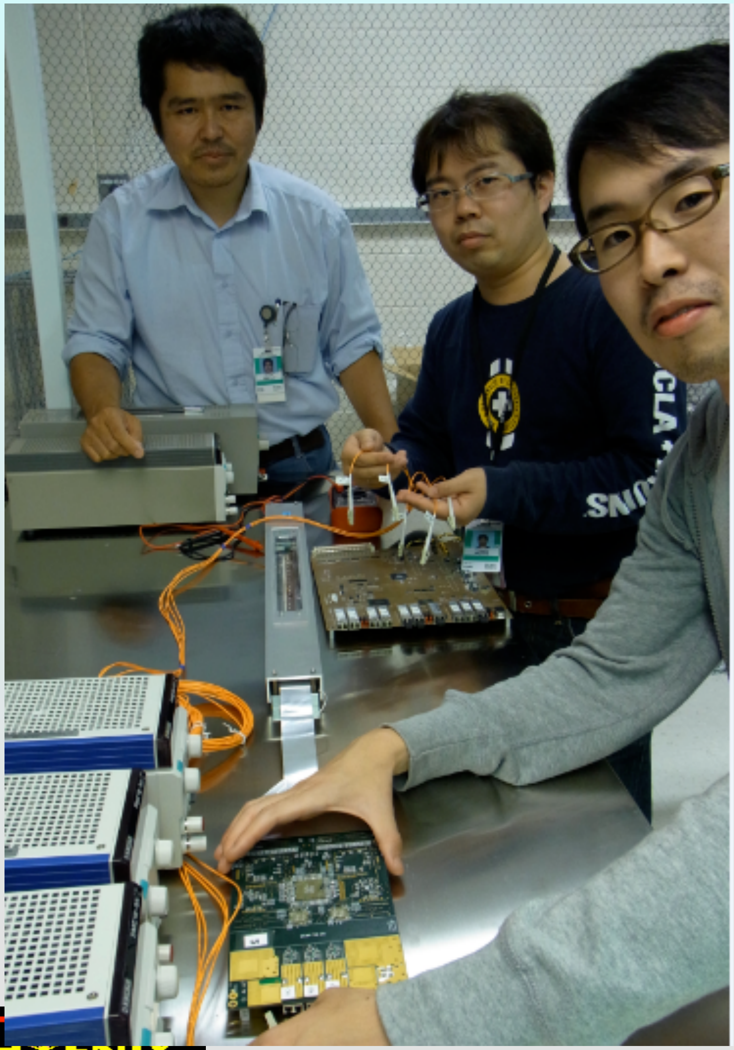
Testing a new ladder

28 ladders out of 40 done

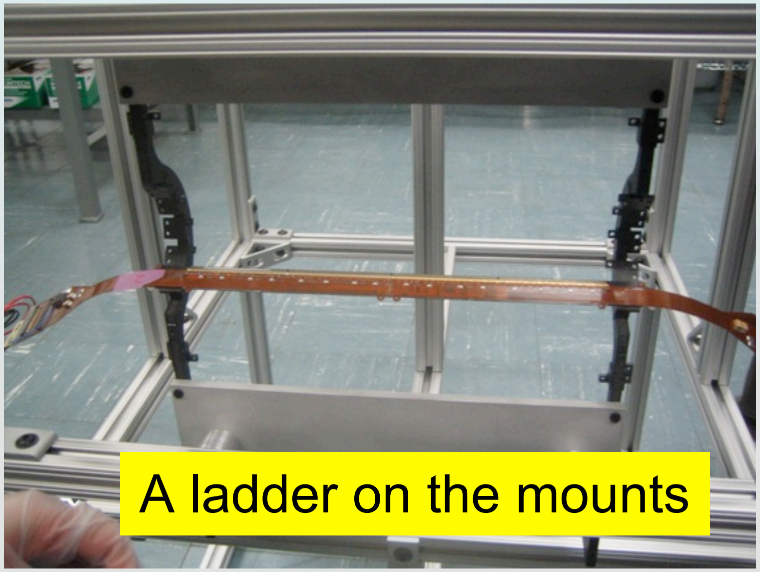


VTX Pixels: Preparing for barrel assembly

16 ladders out of 30 assembled at RIKEN. They will start arriving at BNL soon



Test fit a ladder on the mounts



A ladder on the mounts

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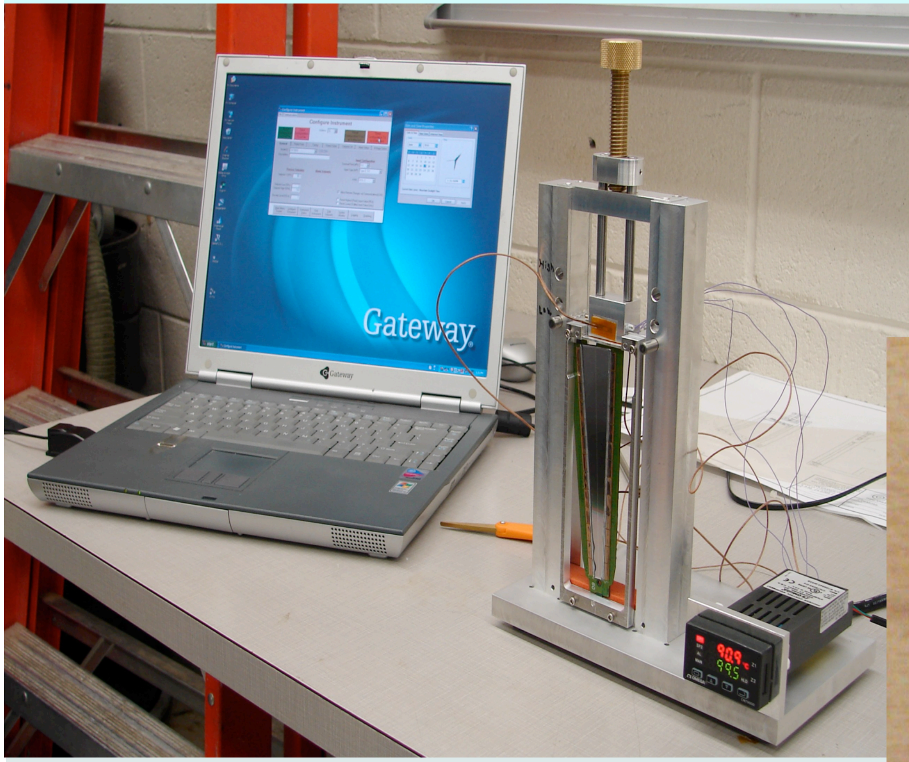
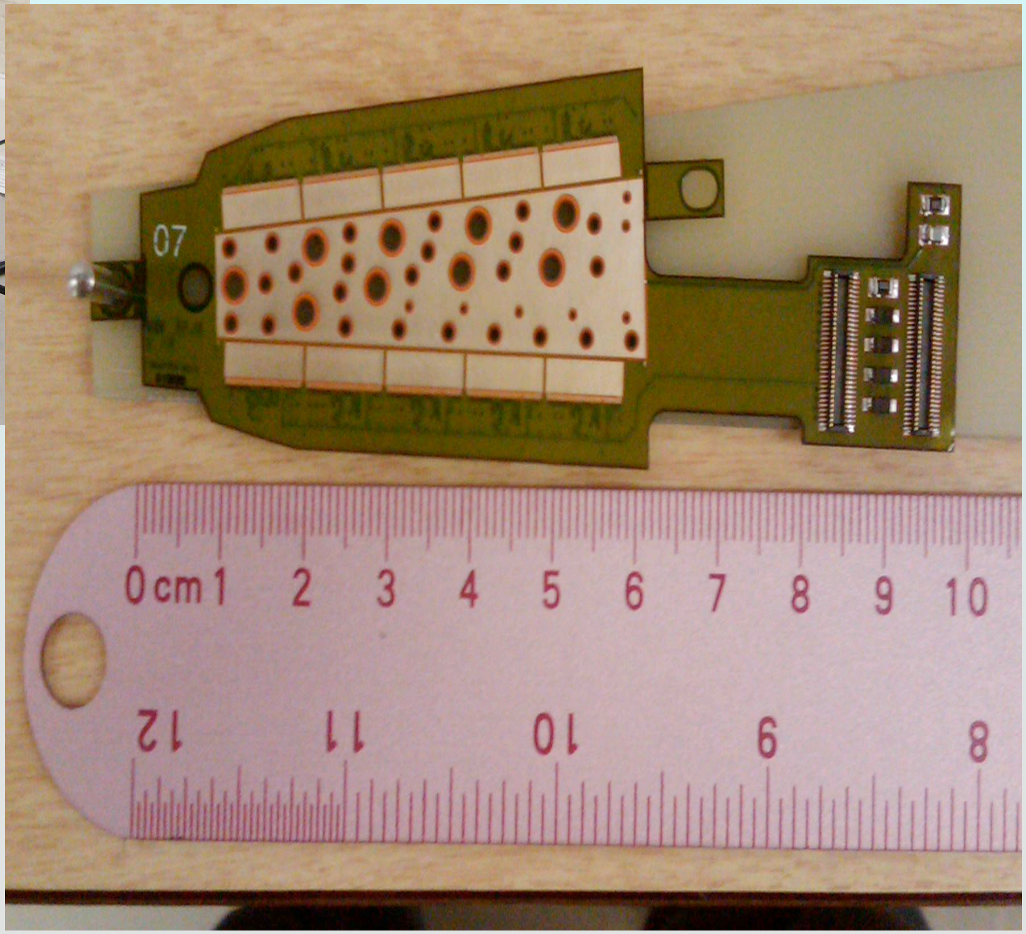
FVTX construction status





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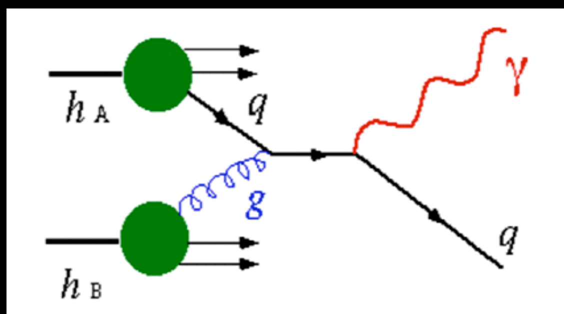
Forward Calorimetry - FOCAL

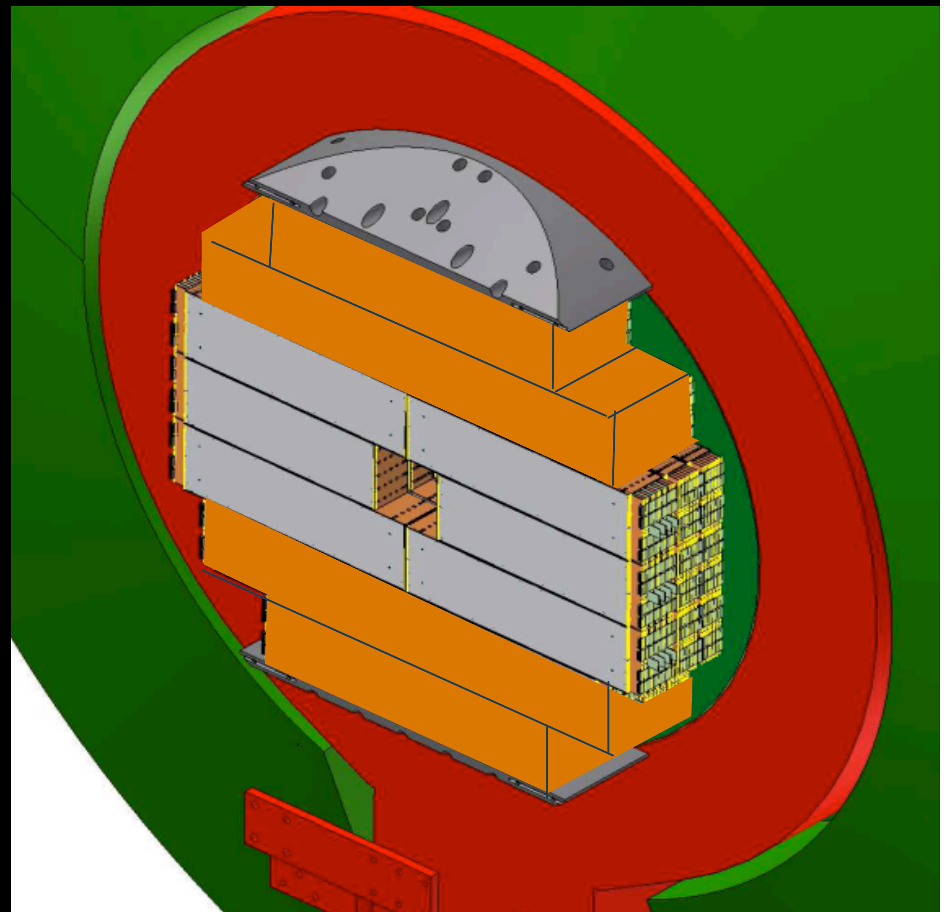
Q: are γ suppressed in d+Au?

- Physics Goal:

  Gluon PDF at low-x via direct photons



- Si-W calorimeter
  - 44cm from the interaction point
  - Modular Brick construction



This is a new type of detector. Excellent test beam results.
Time scale → 2014, Cost scale → $1.8M

Currently under PHENIX internal review

PHENIX Upgrades
in longer term
(Decadal Plan progress)

Is there more after 2015?

Not easy to predict the future, but we expect that the following will be in hand:

Heavy Ions:

1. Full characterization of bulk medium dynamics (e.g. η/s, T, ε)
2. Completion of Low Energy scan for critical point
3. Experimental measure of charm/beauty dynamics $p_T \sim 6$ GeV
4. Parton energy loss via jets for interaction mechanism: started

Spin:

1. W→lepton measurements to constrain Δu, Δubar, Δd, Δdbar
2. Completion of gluon Δg via π^0, η, $h^{+/-}$ A_{LL} @ 200 and 500 GeV
3. A_N measurements for hadrons

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Unanswered and Emerging Questions (HI)

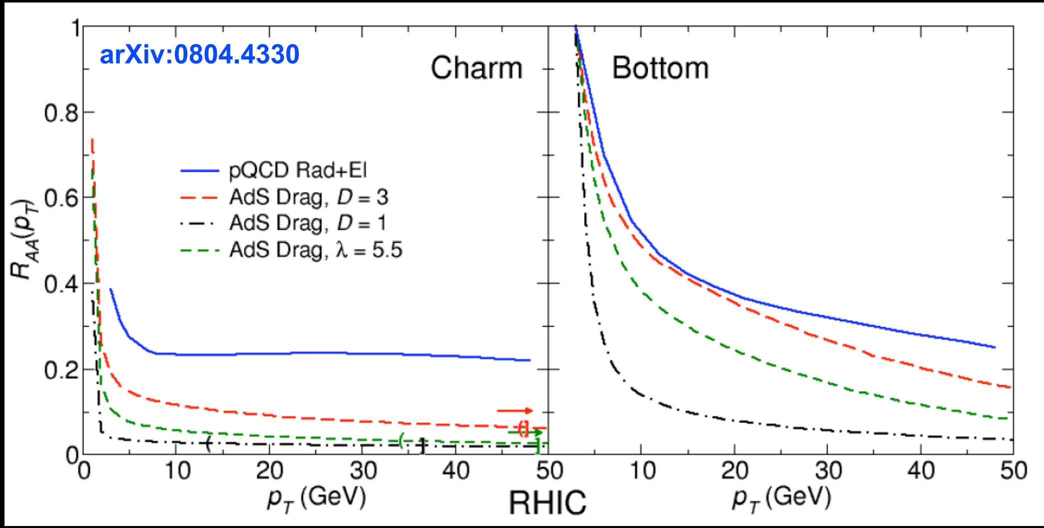
Are quarks strongly coupled to the QGP at all distance scales?

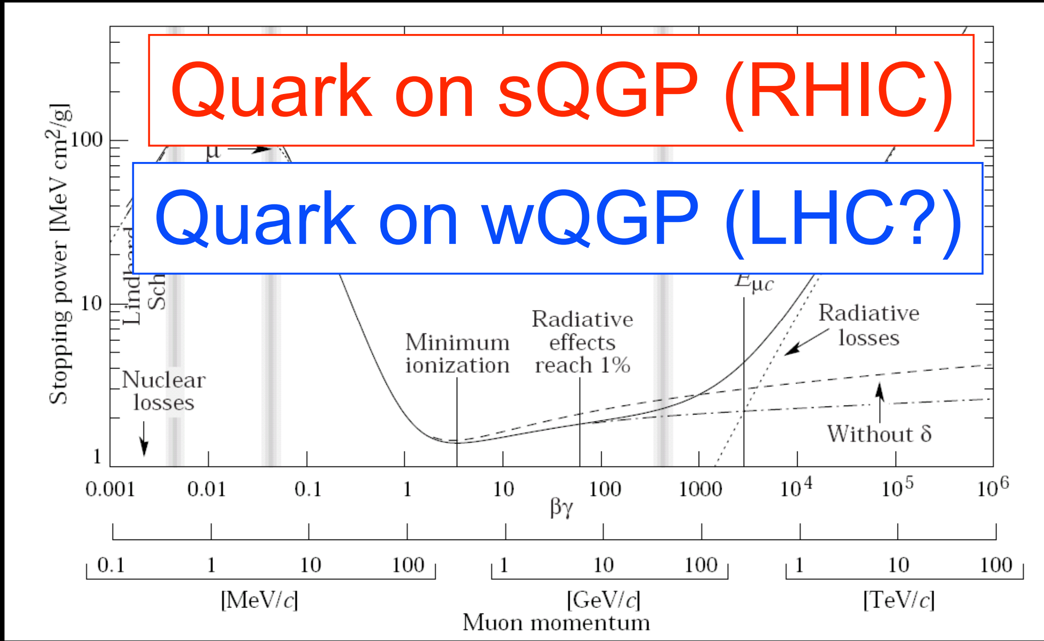
What are the detailed mechanisms for parton-QGP interactions and responses?

Are there quasiparticles at any scale?

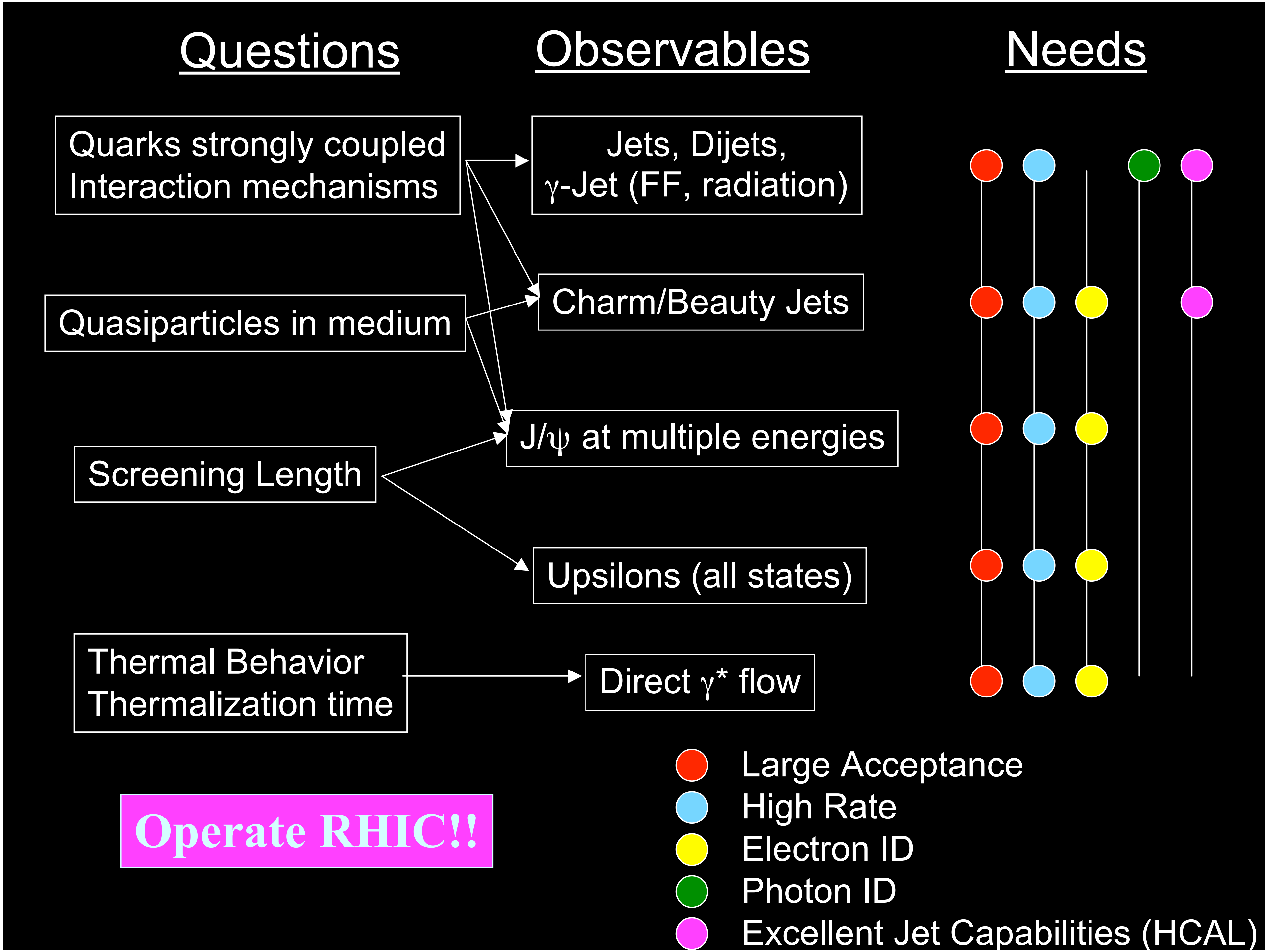
Is there a relevant screening length in the QGP?

How is rapid equilibration achieved?



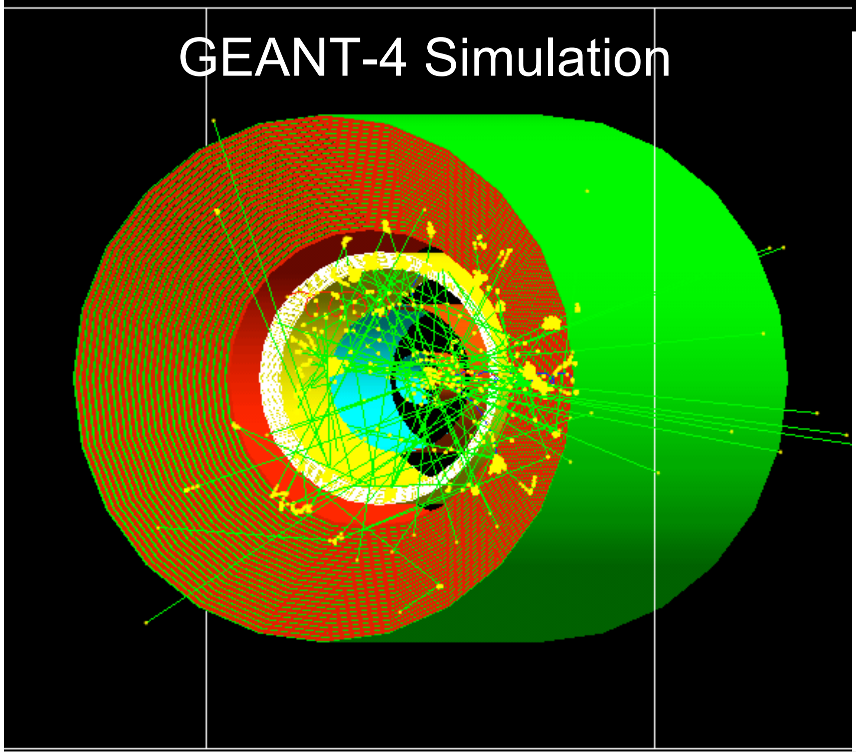


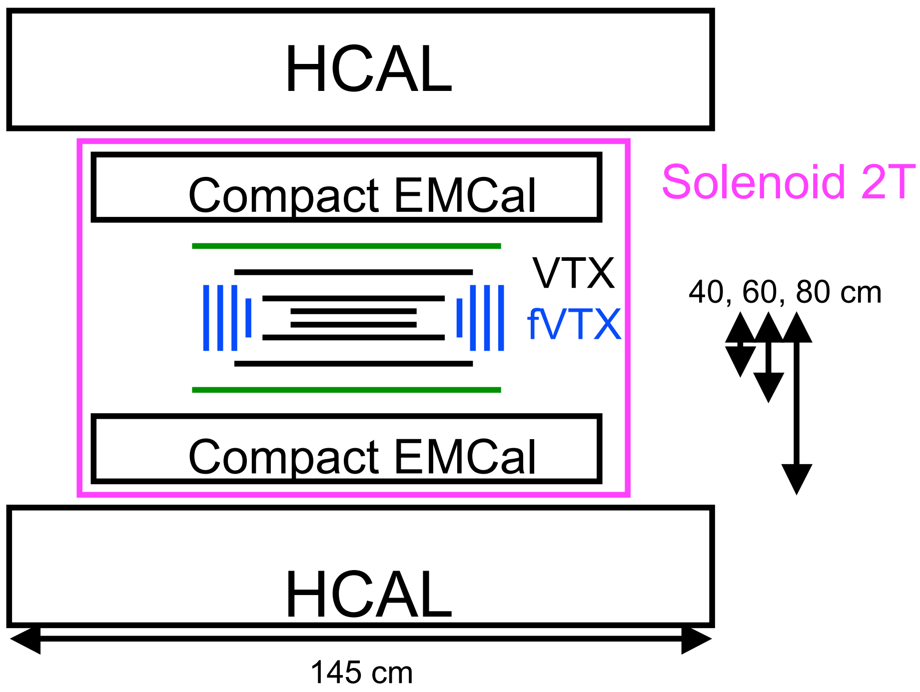
What is needed to answer these questions?


Questions
Observables
Needs
Quarks strongly coupled
Interaction mechanisms
Jets, Dijets,
γ-Jet (FF, radiation)
Charm/Beauty Jets
Quasiparticles in medium
J/ψ at multiple energies
Screening Length
Upsilons (all states)
Thermal Behavior
Thermalization time
Direct γ* flow
Large Acceptance
High Rate
Electron ID
Photon ID
Excellent Jet Capabilities (HCAL)
Operate RHIC!!

PHENIX Upgrade Concept (Compact Detector)

- Current inner silicon vertex tracker
- New solenoid (B = 2 Tesla and inner radius = 70 cm)
- New silicon tracking layers at 40 and 60 cm
- Compact EmCal (Silicon/Tungsten) $|\eta|<1.0$
  8 cm total depth and preshower layer
- Hadronic Calorimeter Outside Magnet
- Maintain PHENIX high DAQ bandwidth and triggers



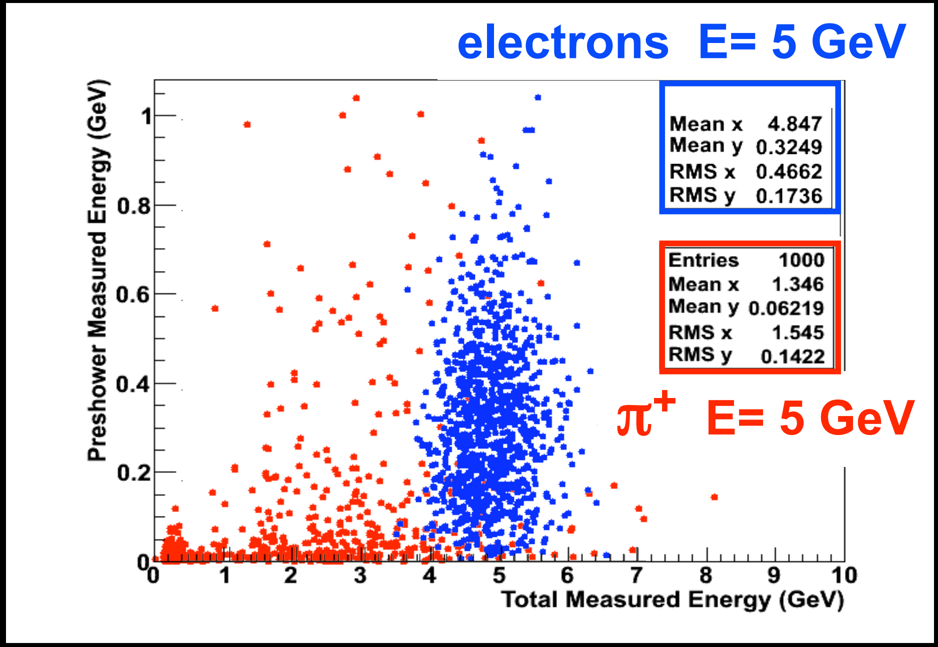


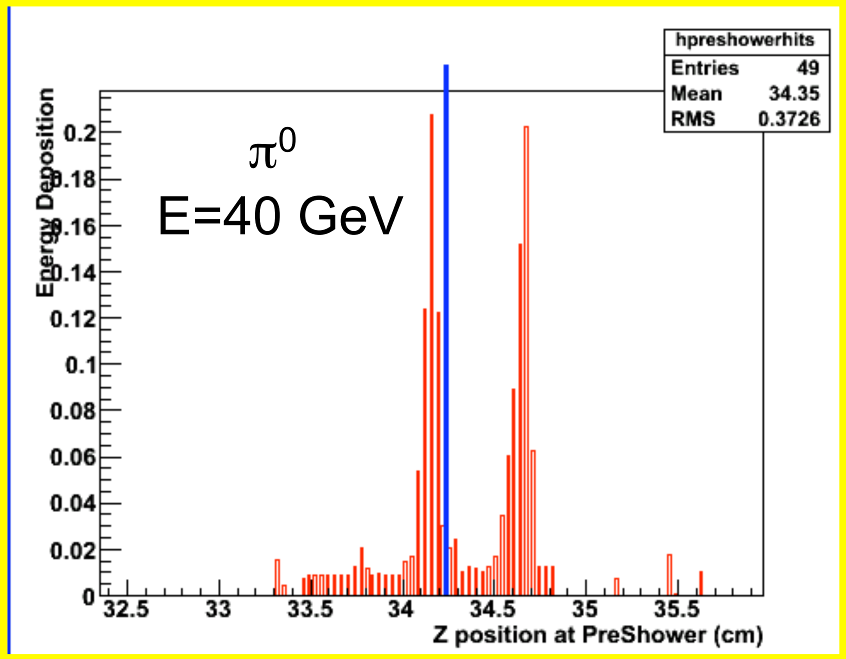
GEANT-4 Performance Evaluation Underway

Excellent electron-ID for p_T > 2 GeV

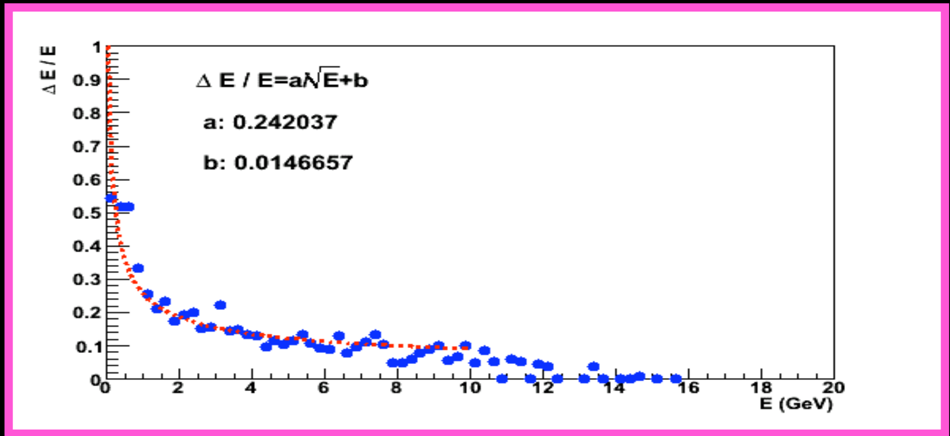
Need detailed study at lower p_T as well.

γ/π^0 separation over full kinematics > 50 GeV





Energy Resolution

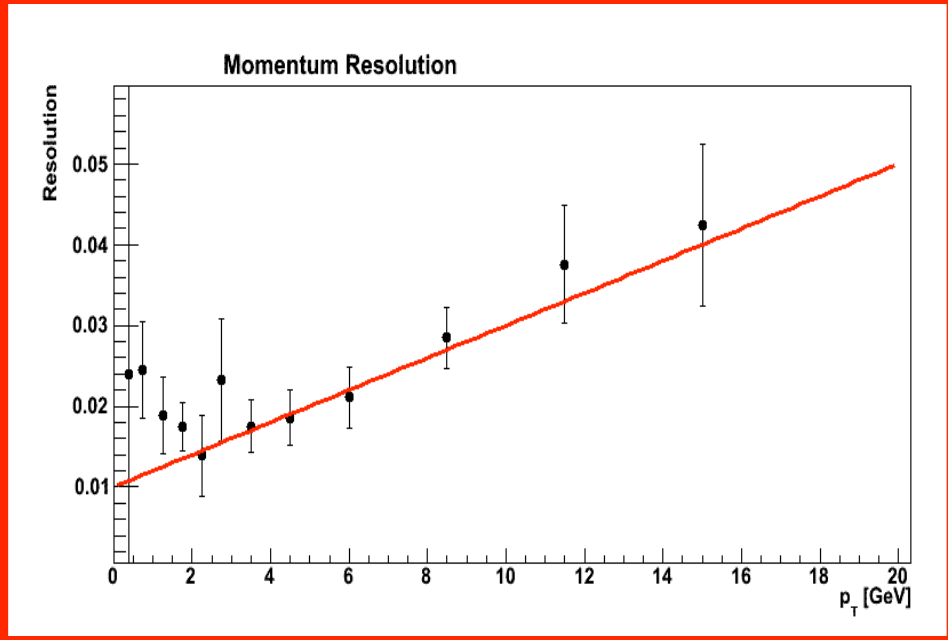


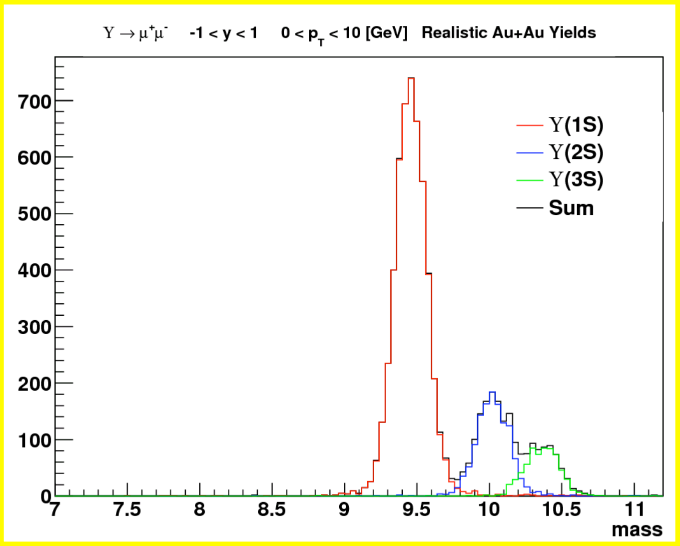
Alex Linden-Levy (LLNL)

GEANT-4 Performance Evaluation Underway

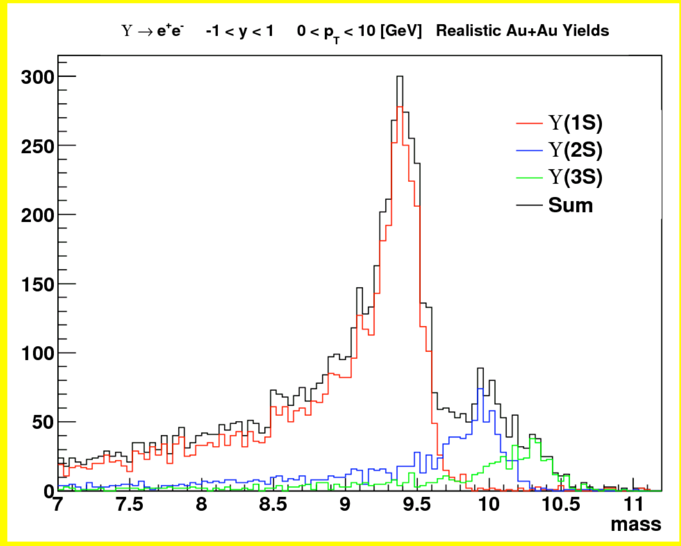
Very good momentum resolution.

Evaluation of fake high p_T track rate underway.





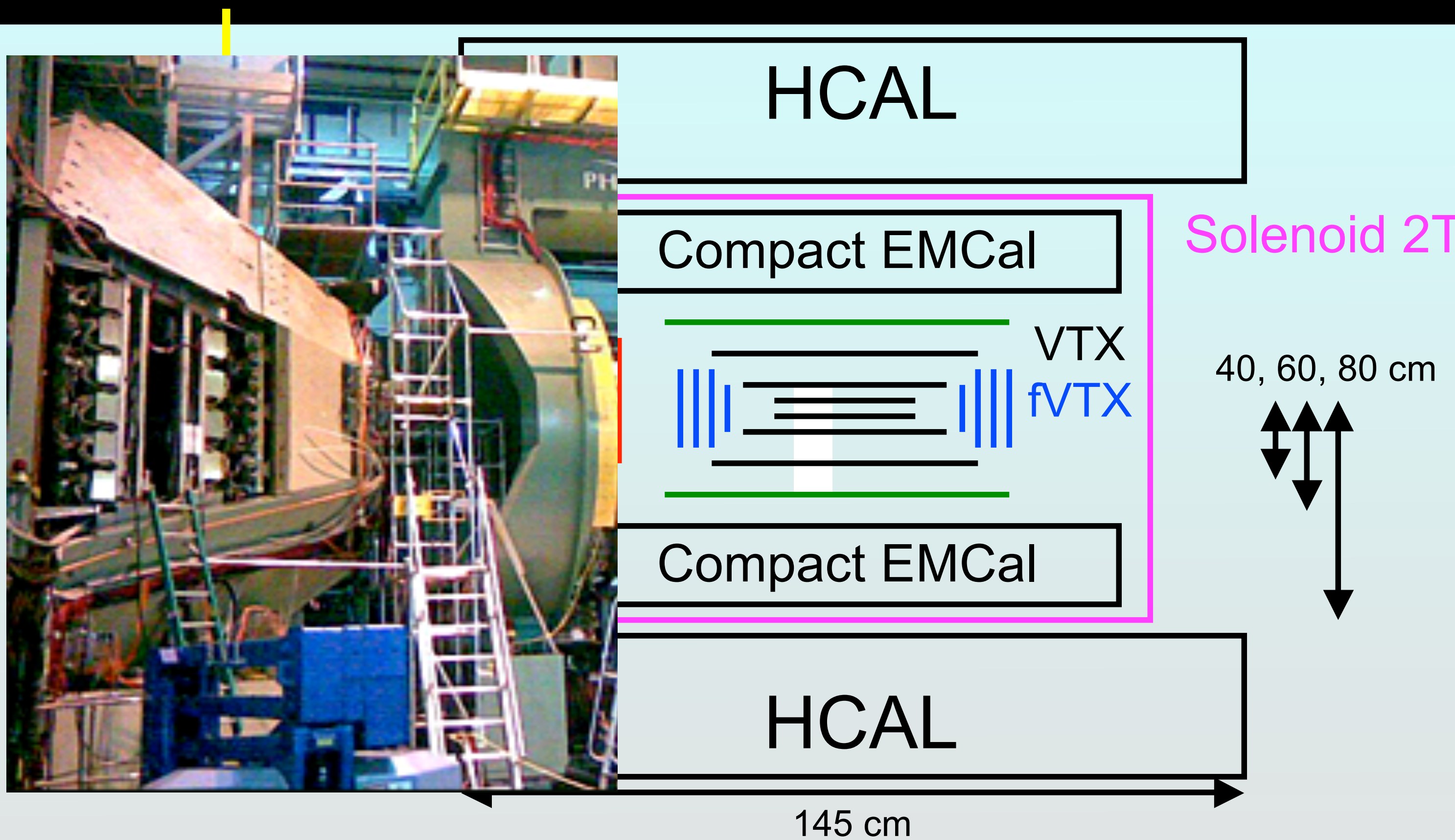
Upsilon Separation of States (with very different binding energies)



Darren McGlinchey (FSU)

Proposal: in 2015 remove the south muon spectrometer $|\eta|$=1.2-2.2 and replace with electron/photon endcap spectrometer $|\eta|$=1.2-4.0

Current Lead-Scintillator and Lead-Glass PHENIX central arm EMCal



Transverse Drell-Yan measurement
Collins/Sivers measurements
ePHENIX capabilities

PHENIX

RHIC resource decisions

- PHENIX priorities
  - Set by PHENIX Management
    - in consultation with EC, DC & collaborators
  - Operational needs communicated by Operations Director Ed O'Brien
  - Upgrades & RHIC capabilities needs communicated by Spokesperson Barbara Jacak
  - Upgrades proposals developed by collaborators
- Issue is balancing competing needs & timescales
  - Capital equipment $ decisions: Tom Ludlam/Ed O'B
  - R&D $ decisions: Currently Ludlam/O'Brien
  - Accelerator/experiment balance: ALD Steve Vigdor discusses with Spokespersons
  - Accelerator concerns apparently higher weight impacts experimental "efficiency" value

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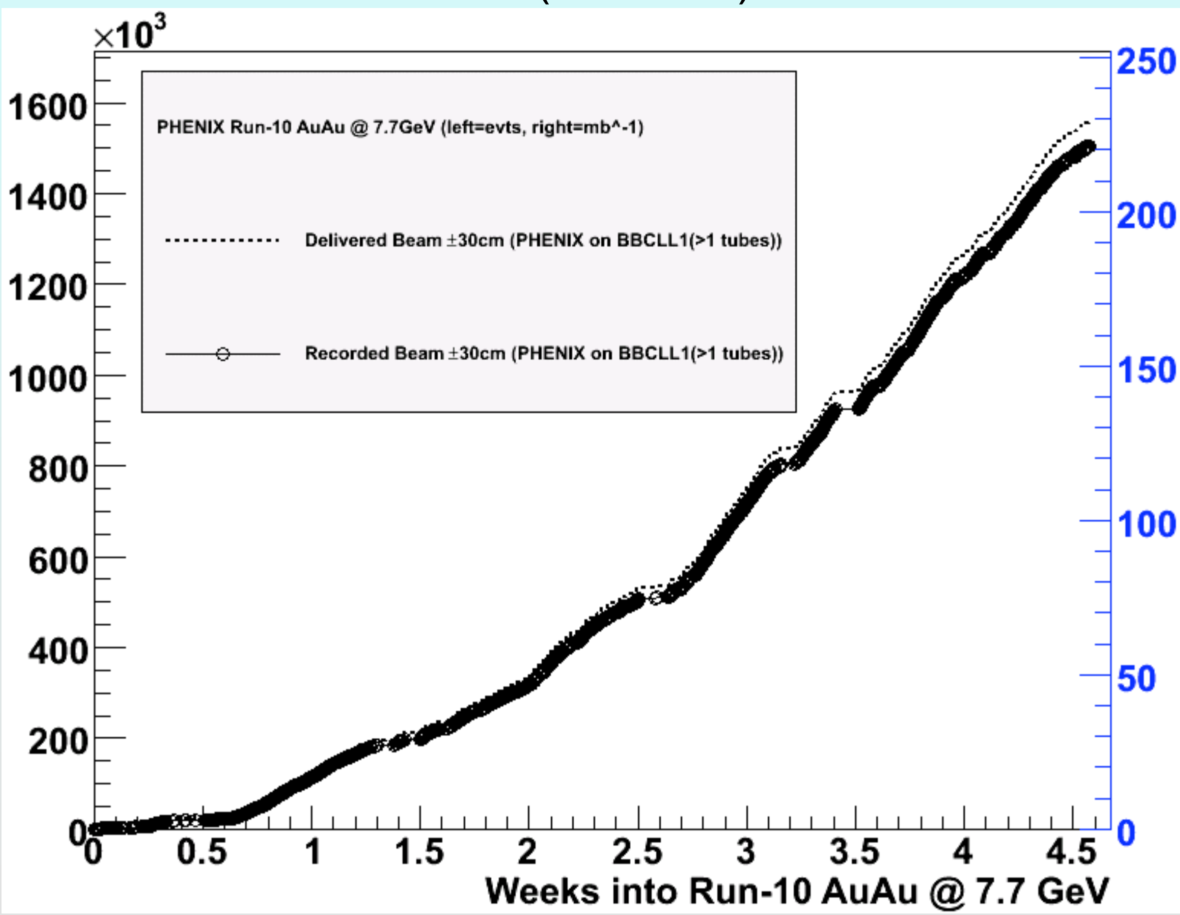
- backup slides

7.7 GeV: April 25—May 27

BBCLL1(>1 tubes)



1.5 M minimum bias events recorded @ 7.7 GeV (twice better than

$\sqrt{s_{NN}}$	Fluctuations in $\langle n \rangle$	Fluctuations in $\langle p_t \rangle$	PID spectra, identified particle ratios	longitudinal density correlations critical exponent η
5.5	0.01	0.03	0.03	2
7.7	0.01	0.03	0.02	2

CAD projects that in 2009 with full Voltage on 200 MHz storage cavities and longitudinal stochastic cooling, zvertex σ = 20 cm, thus having 86% of interactions with ±30 cm window.

Electron cooling projections had 84% of interactions within ±10 cm.

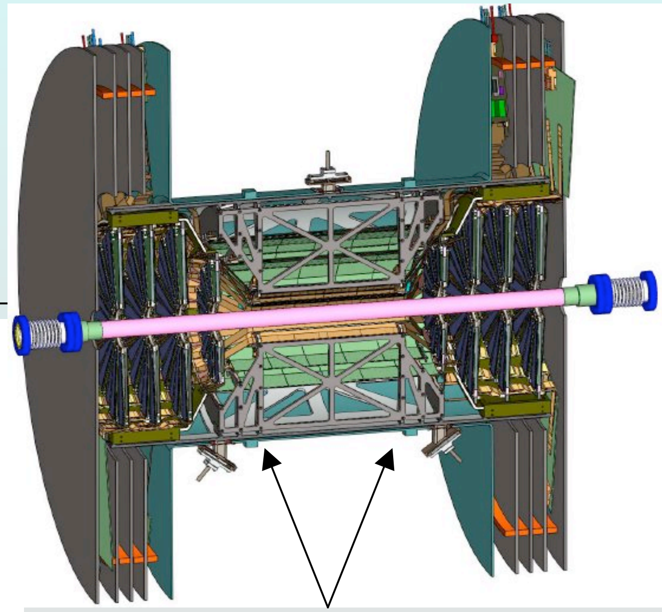
Silicon upgrades to PHENIX (and STAR) spec'ed to utilize collisions within ±10 cm.

However, with stochastic cooling only 50% of interactions within ±10 cm.

Subset of PHENIX measurements can still utilize ±30 cm (e.g. $J/\psi \rightarrow \mu\mu$).

New BBC Level-1 trigger with multiple z-vertex cut capability is being designed.

CAD is already looking into options to address this issue.



Support Structures at zvertex ±11 cm

(C) Livetime Efficiency

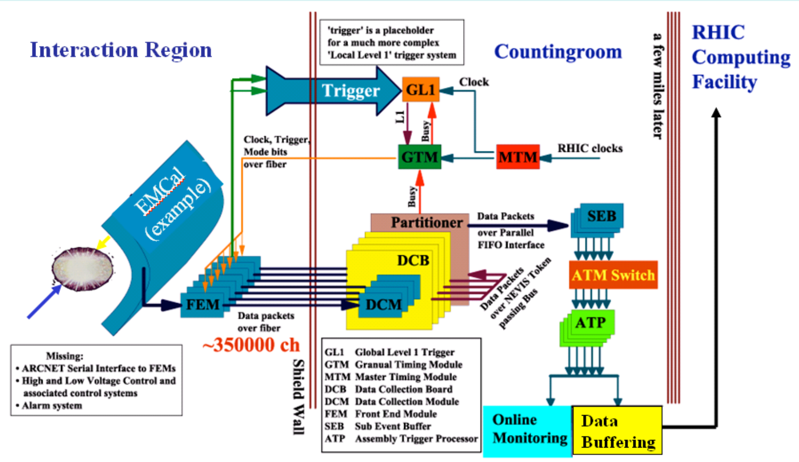
"Livetime" is defined as the fraction of delivered luminosity sampled by the PHENIX Level-1 triggers when the DAQ is running.

Year	2007	2007 (last 2 wks)	2008	2008
Species	Au+Au	Au+Au	d+Au	p+p
Livetime	82%	90%	89%	89%

PHENIX has a fully pipelined "deadtimeless" DAQ (+Front End Electronics and Triggers).

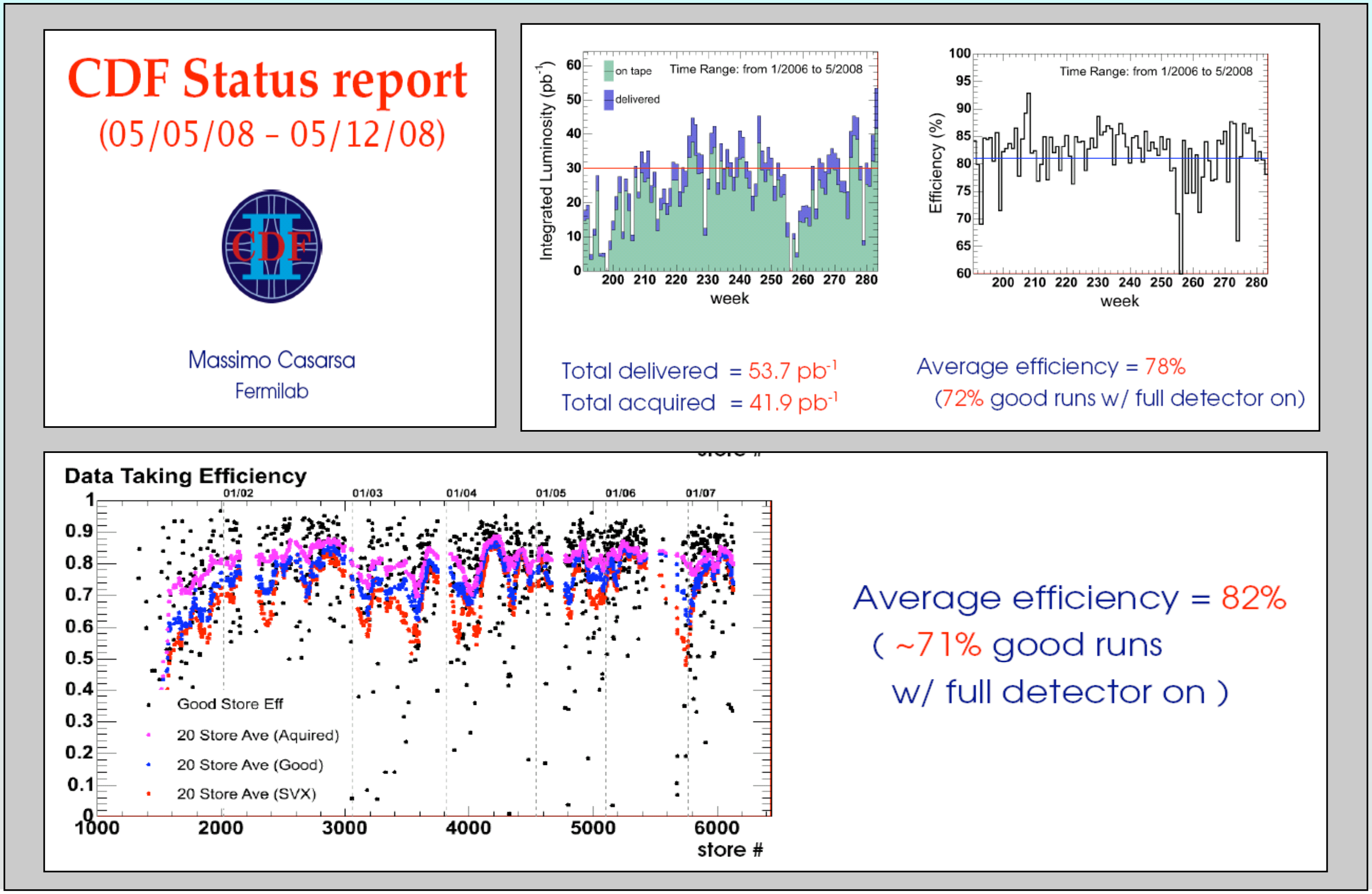
Similar to CDF,D0 (with slower clock) and ATLAS, CMS (with faster clock).

Thus, we can run at close to Level-1 trigger capacity at very high livetime.



Level-1 triggers: Interaction triggers (BBC, ZDC)
Muon triggers (MuID)
Photon triggers (EM Calorimeter)
Electron triggers (EM Calorimeter + RICH)

PHENIX "Efficiency" is comparable with other complex high-energy collider experiments.



Note that maximum efficiencies are typically achieved during long running periods with stable conditions - RHIC has not been blessed with many such periods, especially compared to FNAL's multi-year running.

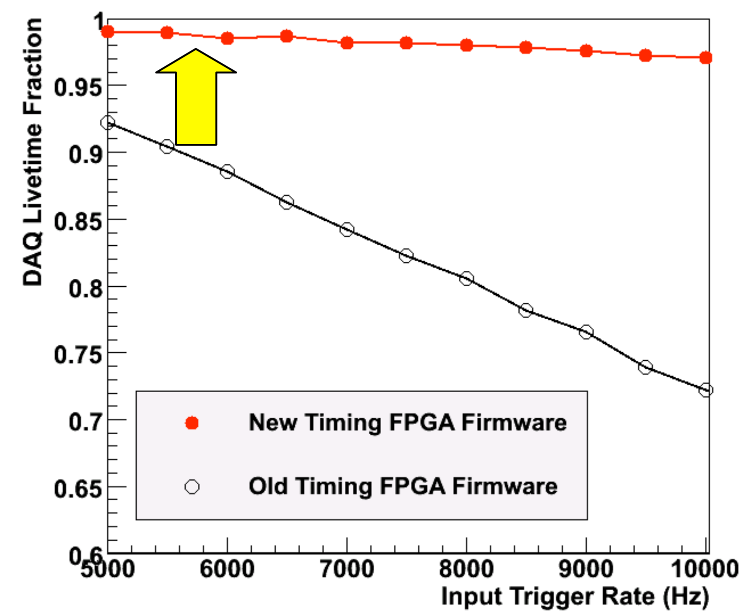
Plans to maintain high DAQ + Trigger Livetime

• New FPGA firmware for timing system (tested in Run-08, in for Run-09)

Should improve p-p livetime 90% → 97%

• New FPGA zero suppression schemes (tested in Run-08, in for Run-09)

• Other improvements underway



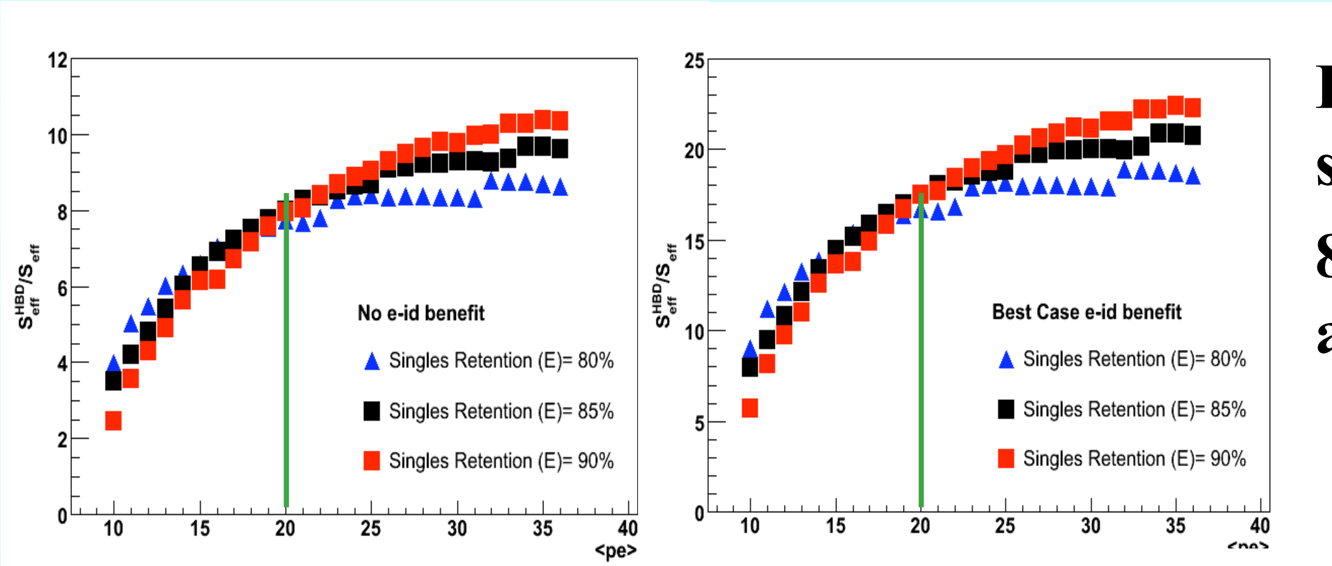
• However, without significant new DAQ hardware for new, large data volume detectors, Level-1 capacity rates will drop down to 2 kHz !

Data Collection Modules II + jSEB II necessary (see next slide)

Evolve Event Builder to 10 Gigabit capacity necessary (and to data buffering boxes).

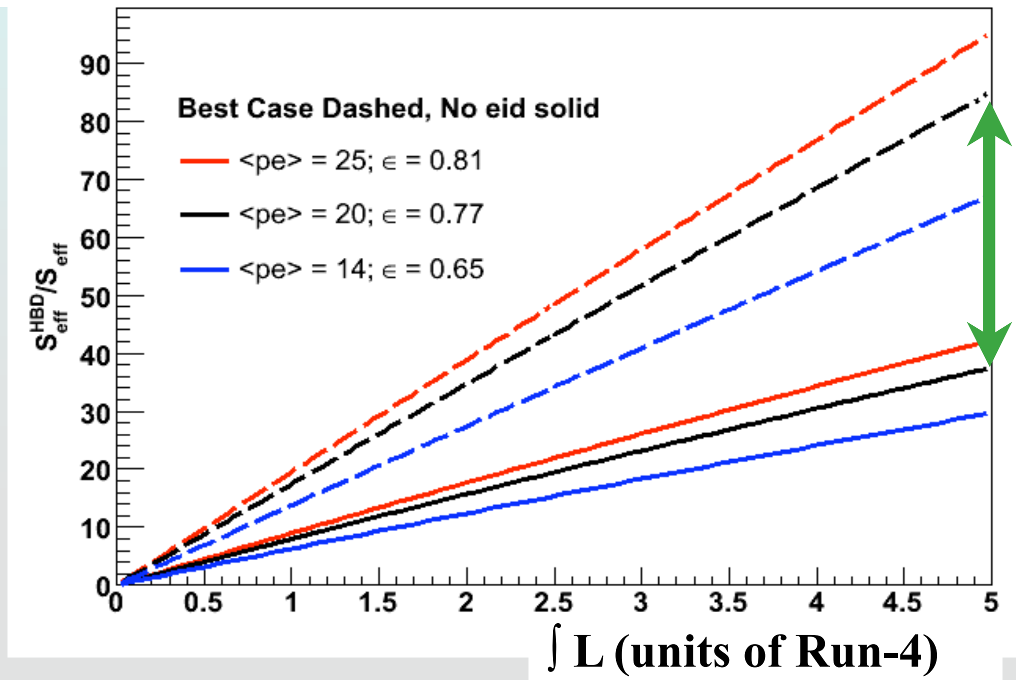
System	Groups	Event Size	Data Rate per Group
VTX Pixel	3	90 kB	1.9 Gb/s
VTX Strip	2	39 kB	1.3 Gb/s
FVTX	6	100 kB	1.1 Gb/s
NCC	2	32 kB	1.0 Gb/s

HBD impact in Run-10 200 GeV Au+Au



Improves effective signal by factor of 8-16 (w/o and w/ added e ID effect)

1.4 /nb recorded improves effective statistics by ≥ 35 vs. old Run-4 result



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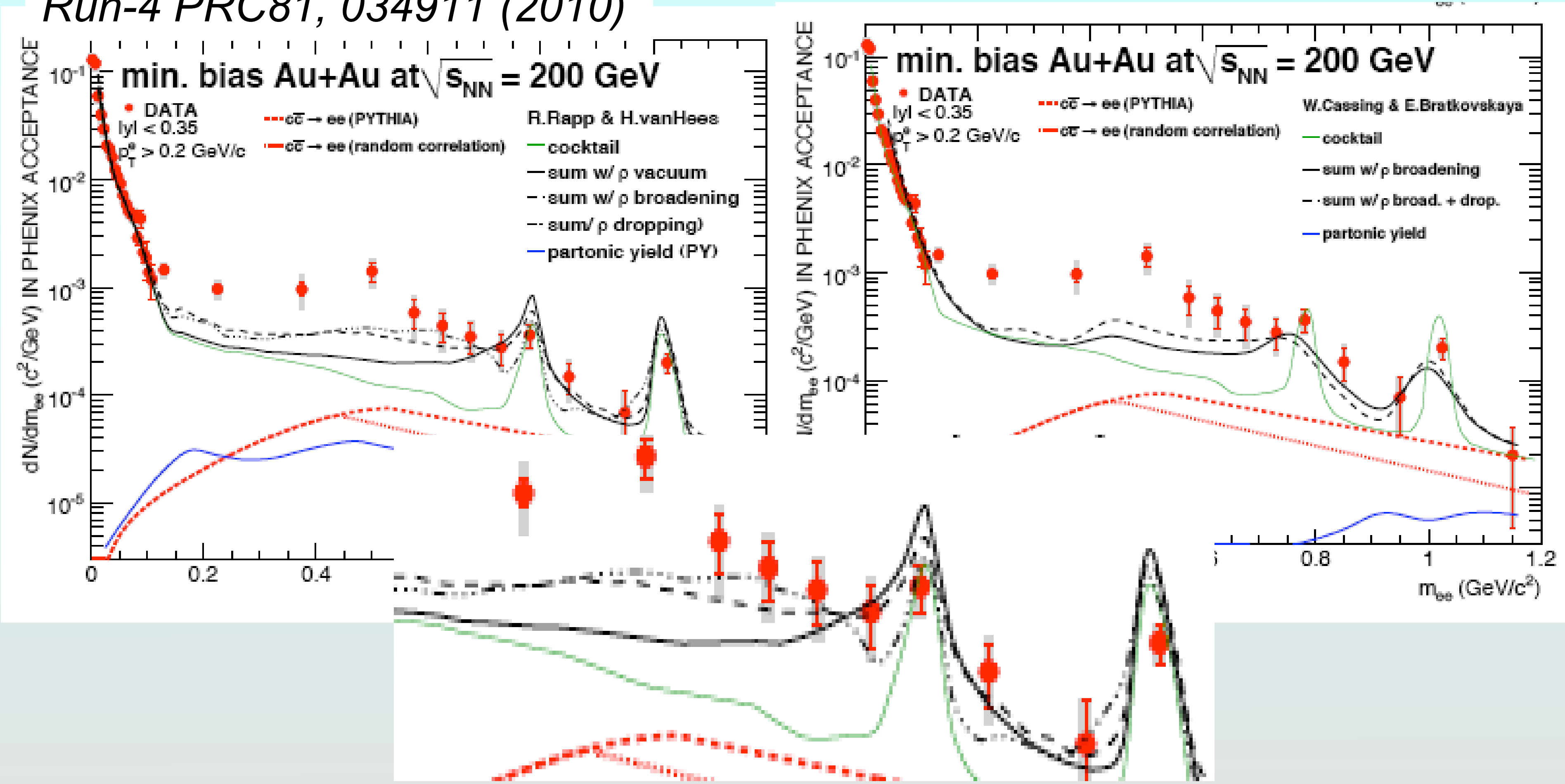
Constraints on in-medium ρ

Run-4 PRC81, 034911 (2010)



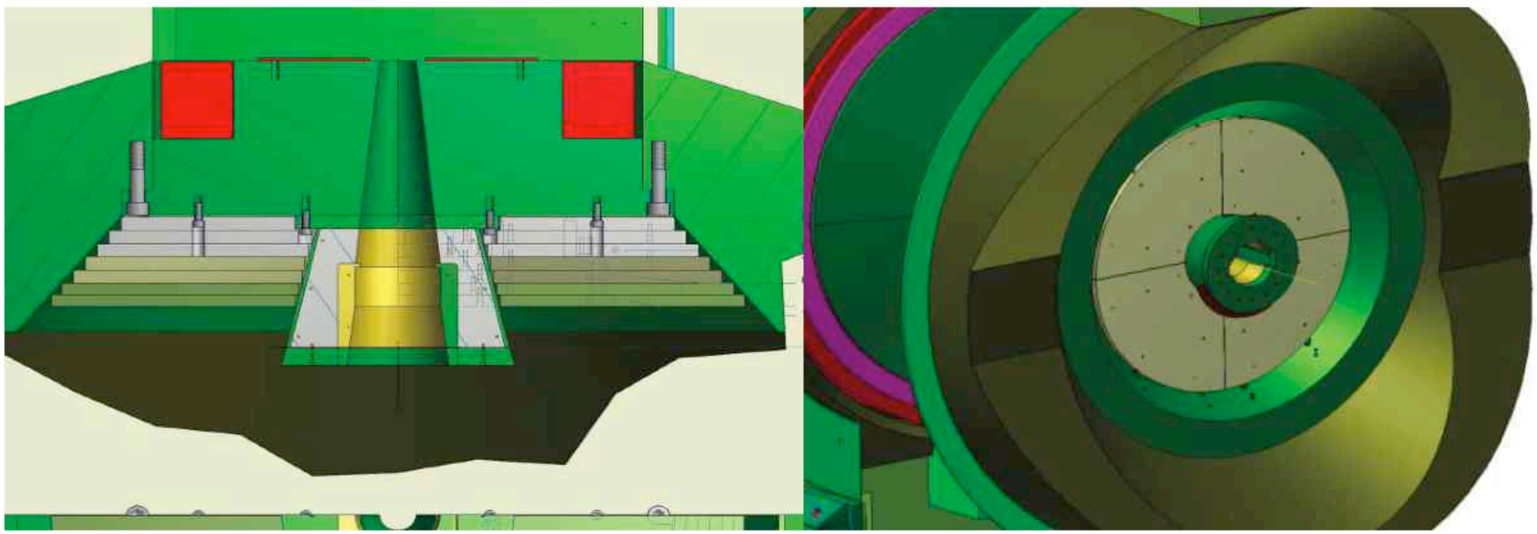
Run-10: decrease σ_{stat} by ~ $\sqrt{35}$ ~ 6, σ_{syst} also?

Modified ρ? 1.5σ effect → 6σ effect??

Muon arm background reduction

Stainless steel SS-130 absorber

2 interaction lengths, based upon simulations



Install on muon arms during shutdown

Parts are ordered.

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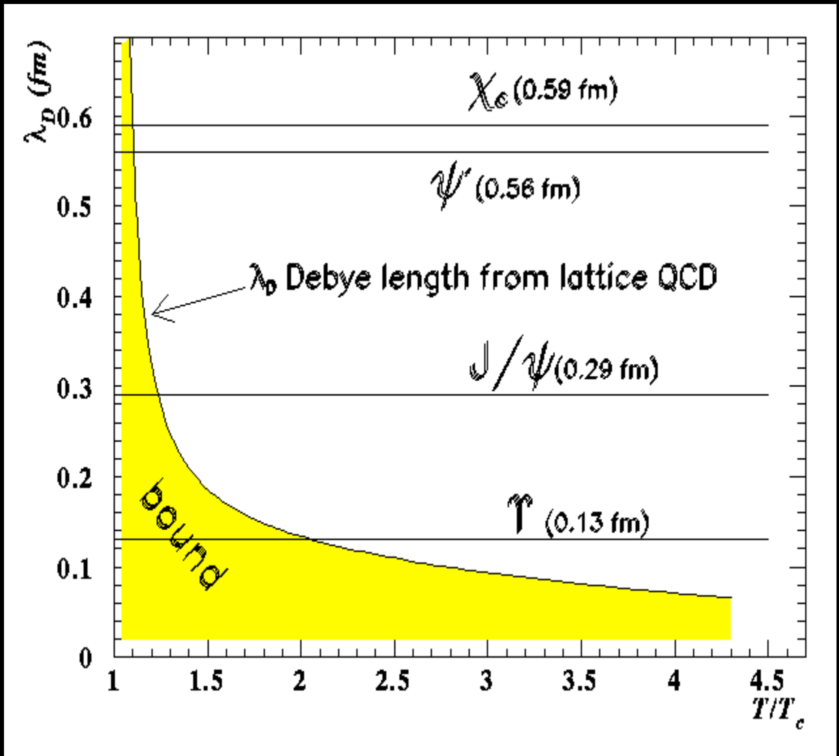
Screening Length

Quarkonia still hold the greatest promise for access to the right distance scales to learn the color screening length in the QGP.

Why Upsilon is very different:

→ J/ψ recombination
→ J/ψ initial nPDF complication
→ Most important is 3 states!



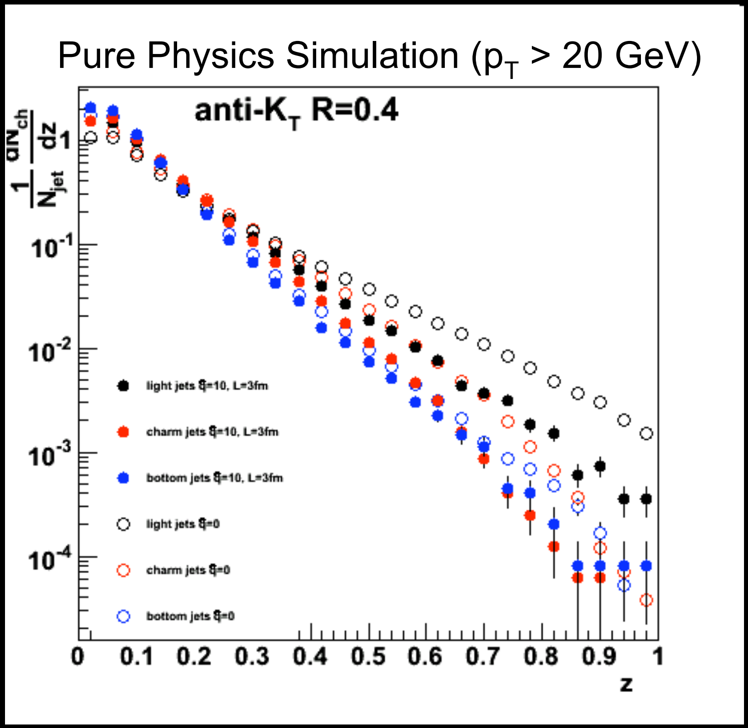
state	J/Ψ	χ_c	ψ'	Υ(1s)	χ_b	Υ(2s)	χ_b'	Υ(3s)
Mass [GeV}	3.096	3.415	3.686	9.46	9.859	10.023	10.232	10.355
B.E. [GeV]	0.64	0.2	0.05	1.1	0.67	0.54	0.31	0.2
T_d/T_c	---	0.74	0.15	---	---	0.93	0.83	0.74

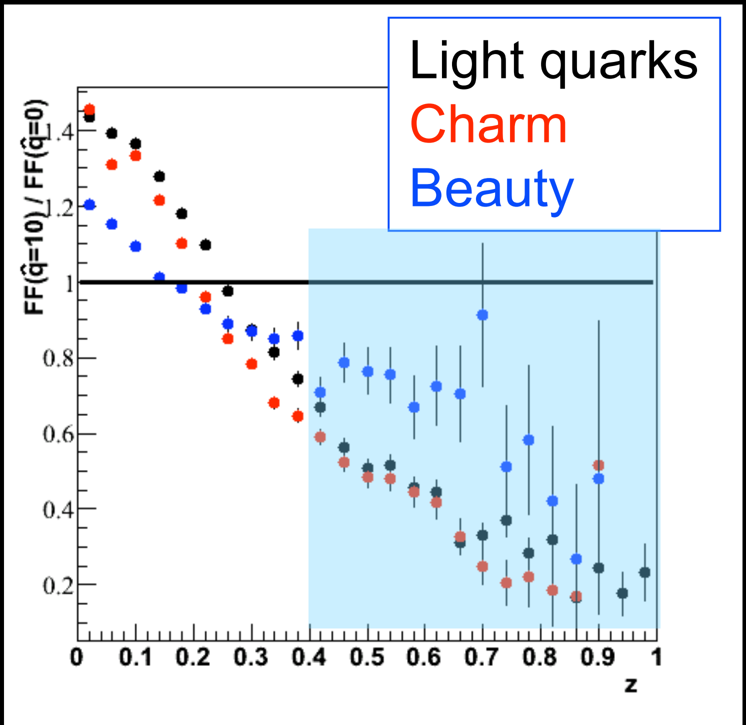
hep-ph/0105234 - "indicate ψ' and the χ_c dissociate below the deconfinement point."

Forward Physics Objectives

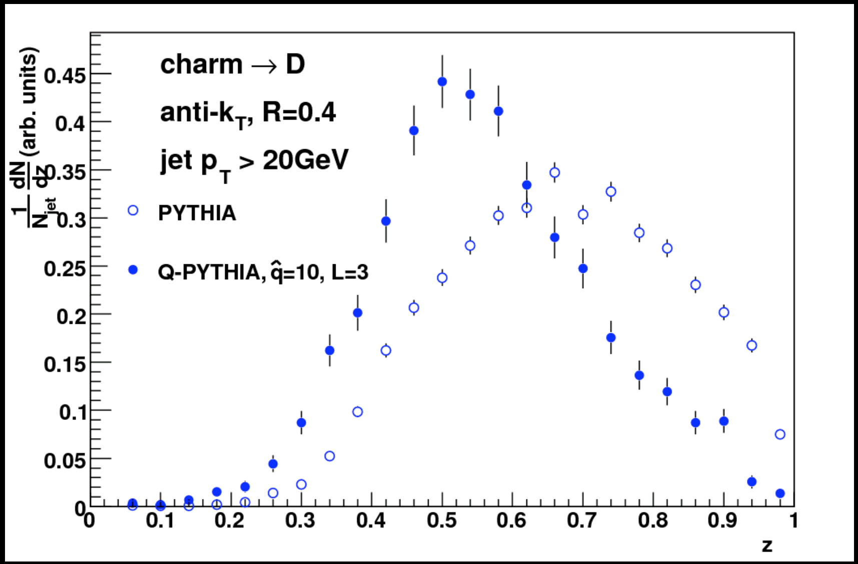
- Transverse spin phenomena
  - Kinematics high x_f, high rapidity $|\eta| > 2$
  - Drell-Yan test QCD prediction for Sivers between SIDIS and DY
  - Separate Sivers and Collins and do a flavor separation for the PDFs
    - π^0-jet, γ – jet, IFF for identified hadrons,
    - jet A_N, direct photon
- Longitudinal spin phenomena
  - high rapidity $|\eta| > 2$ → extend x coverage for ΔG and Δq
- Drell-Yan in dAu
  - Measure quark distributions in nuclei
  - Possible access to quark saturation
- EIC physics
  - Measure polarized and unpolarized inclusive structure functions in ep / eA (F_2, F_L, F_3, g_1, g_2, g_5)
  - "Diffractive physics" (DVCS, etc.)

Modified Fragmentation Functions





Excellent fake track and fake jet rejection needed for this kinematics.

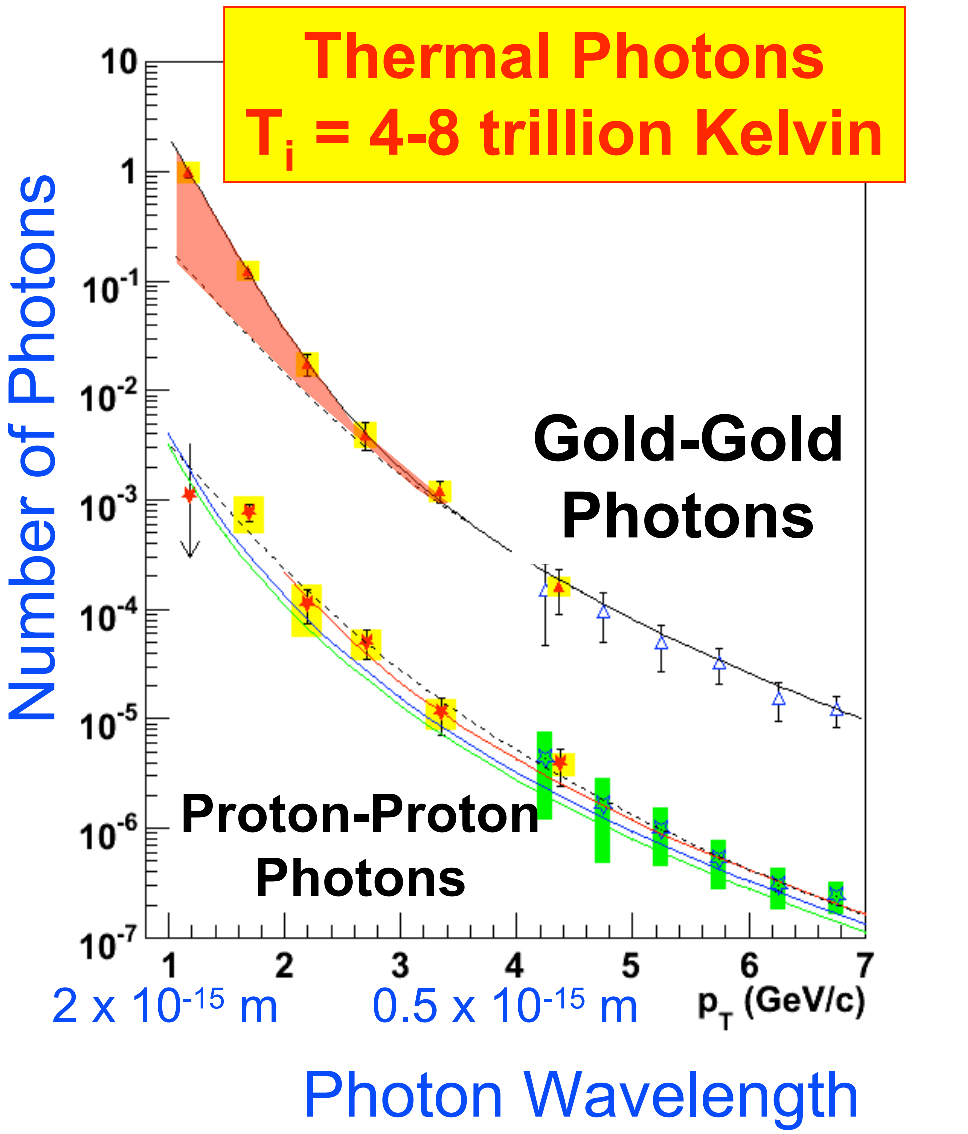


Modified FF for D mesons specifically tags the shift in the leading parton.

We are working out the tagging efficiency.

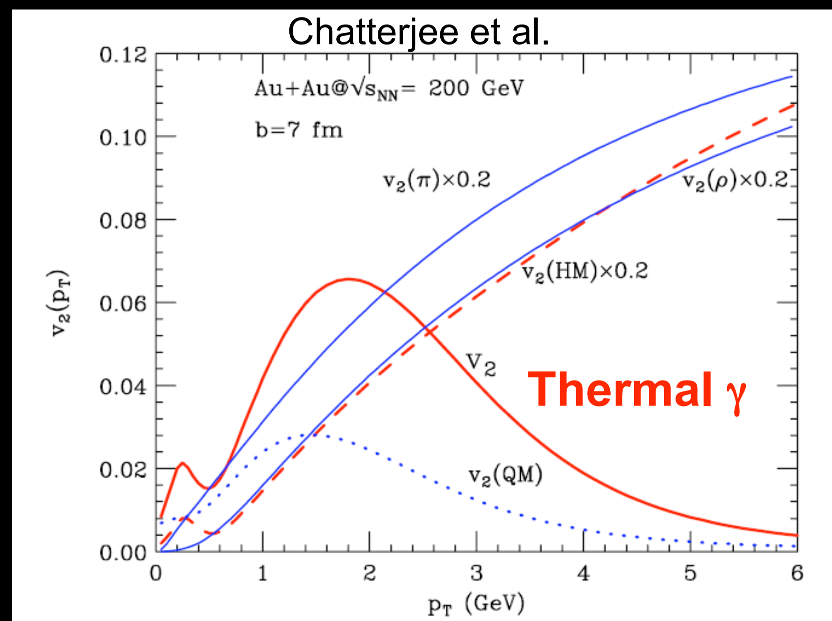
* pQCD – radiative vs collisional (dependent on QGP content)

QGP Temperature



Again, with excellent science, always thinking of new tests.

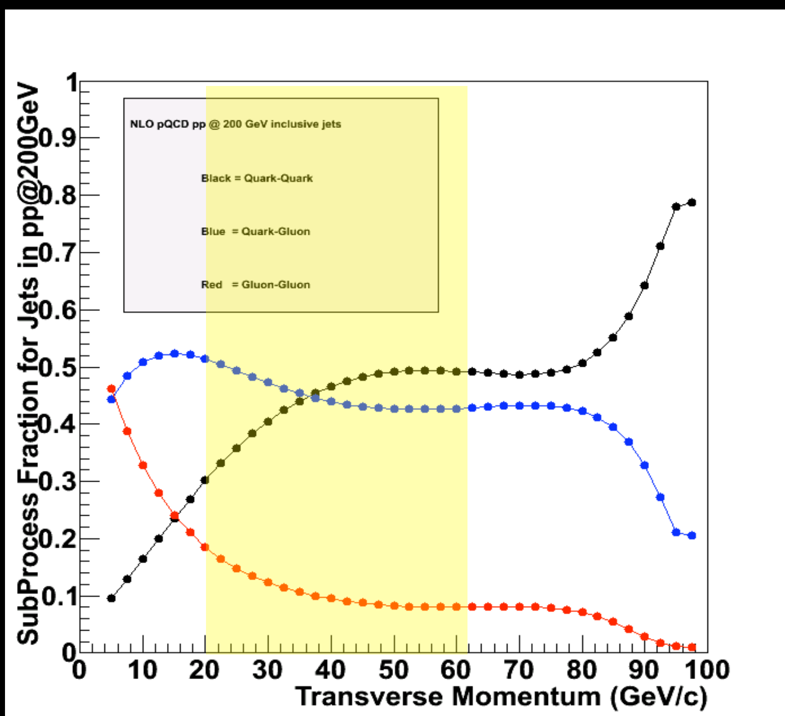
How about v_2 of these photons?

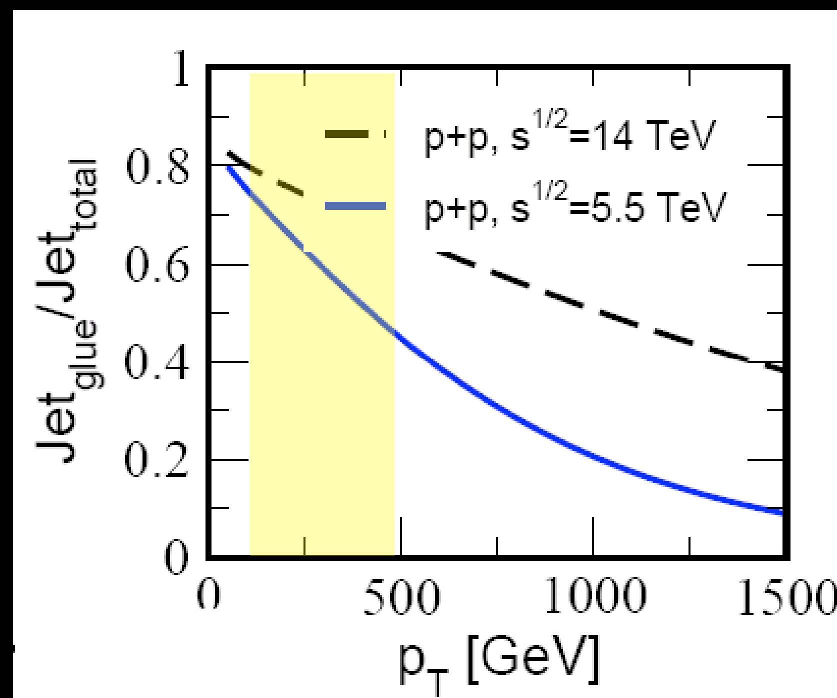


RHIC versus LHC

1. Probe difference
2. Medium difference
3. Key machine flexiblity pA, light AA, …

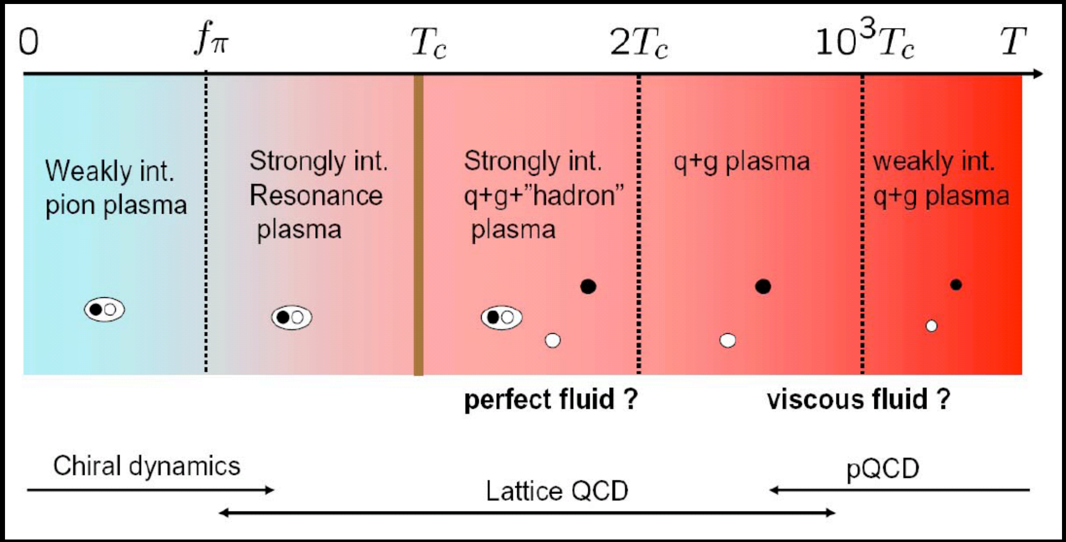
RHIC ~ 75% quark jets LHC ~ 50-75% gluon jets

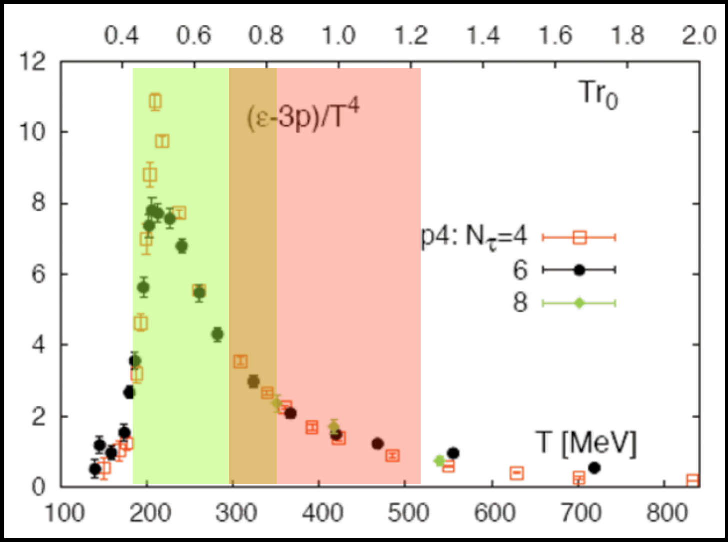




RHIC versus LHC

1. Probe difference
2. Medium difference
3. Key machine flexiblity pA, light AA, …





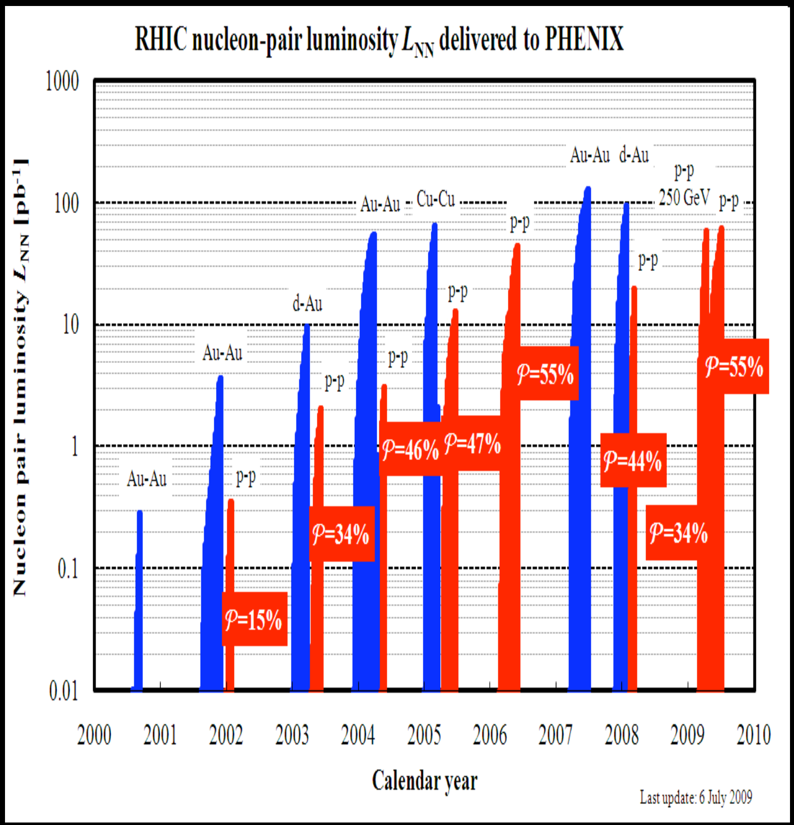
RHIC QGP dominated by 1-2 T_c

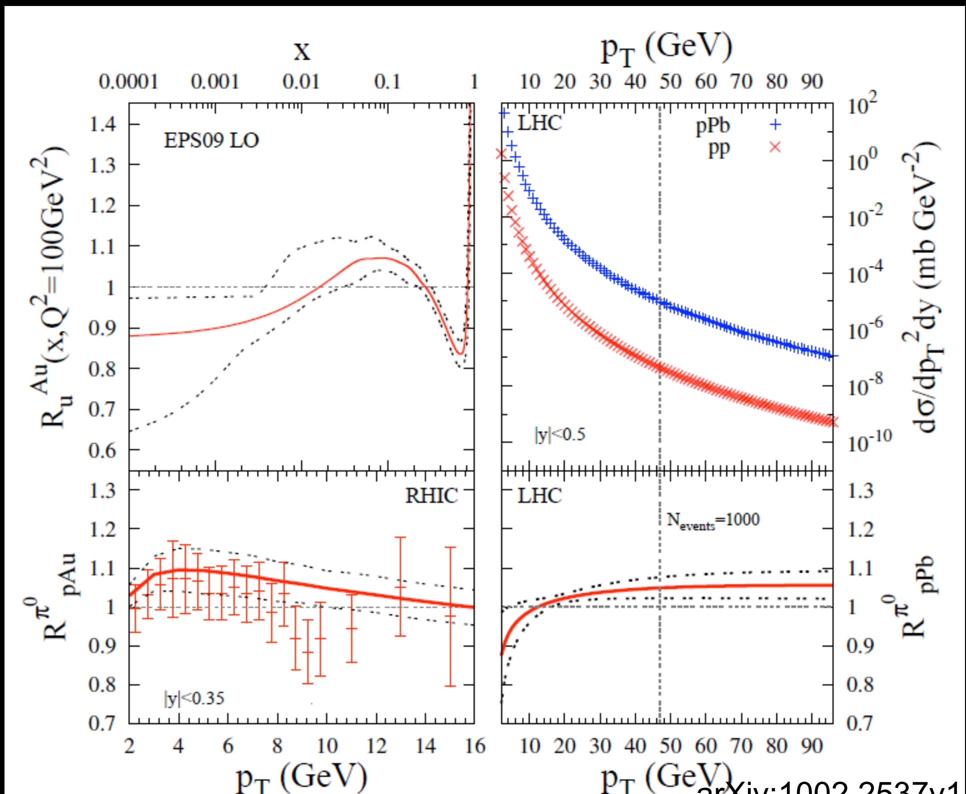
LHC QGP dominated by 2-4 T_c (?)

RHIC optimal for strong coupling studies.

RHIC versus LHC

1. Probe difference
2. Medium difference
3. Key machine flexibility pA, light AA, AA, high rates



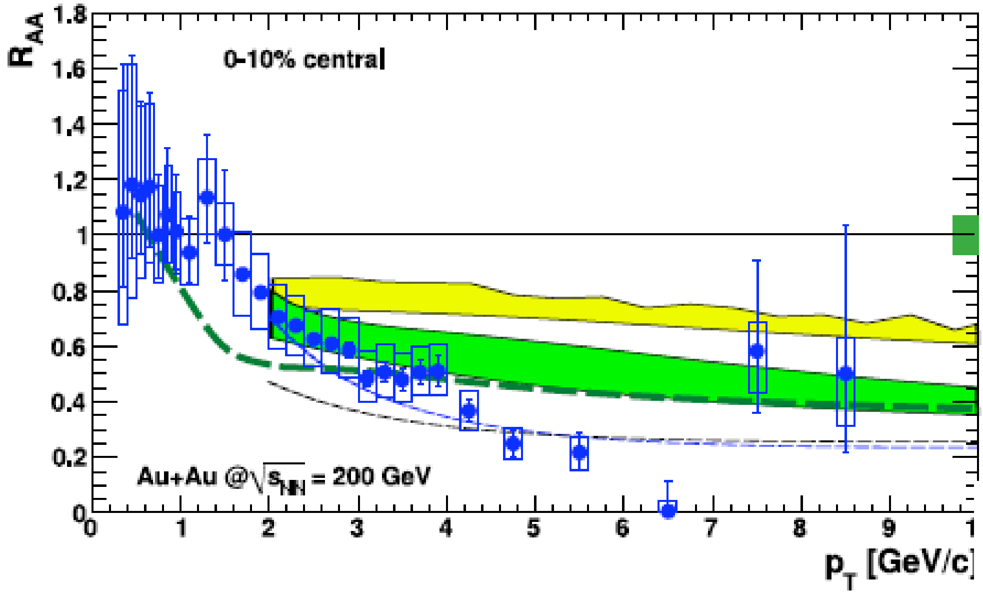


arXiv:1002.2537v1

Q6: heavy quark suppression & flow?

PRL.98: 172301,2007

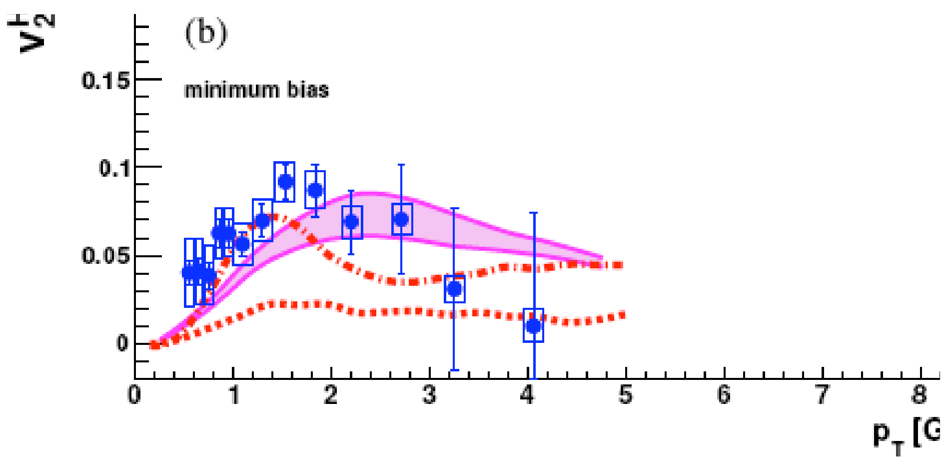
arXiV: 1005.1627

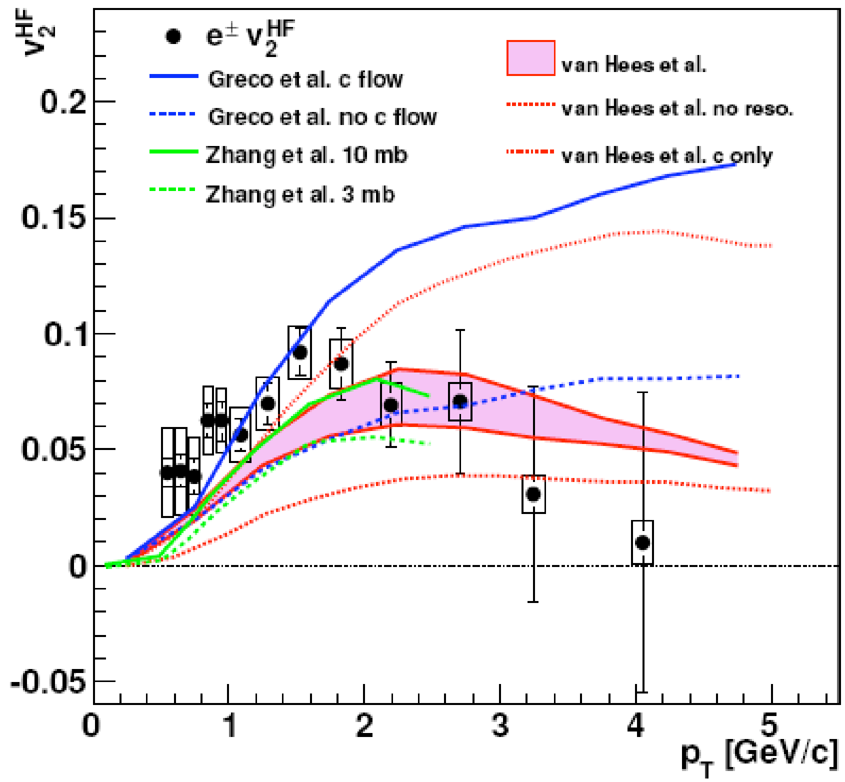


Collisional energy loss?

v_2 decrease with p_T?

role of b quarks?





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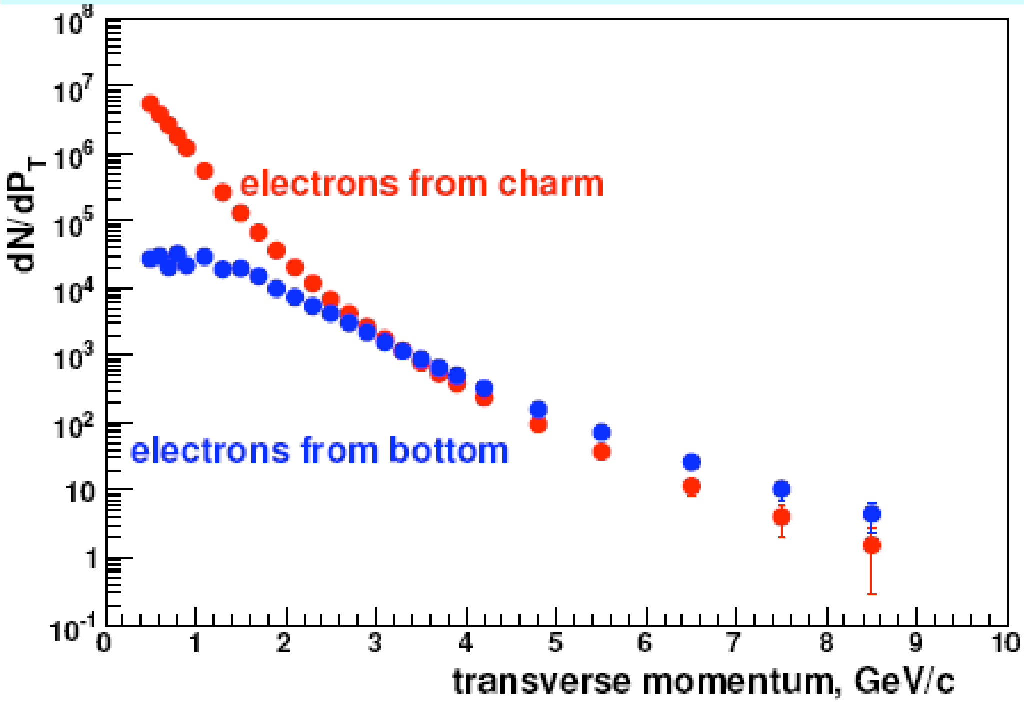
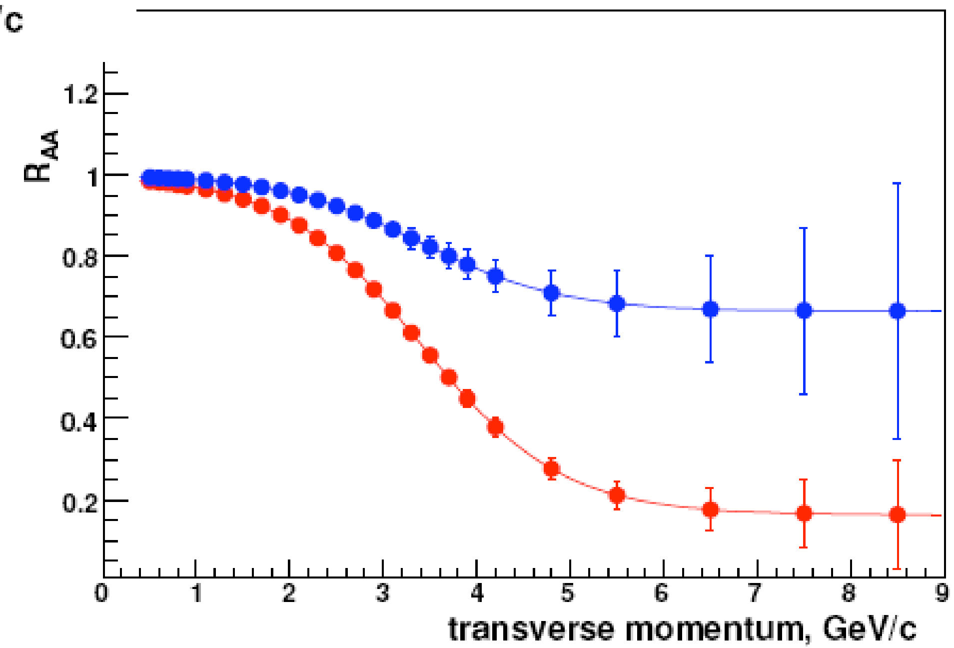
With 8 weeks Au+Au at √ s = 200 GeV



Assumption here:
Full 8 weeks used for data taking



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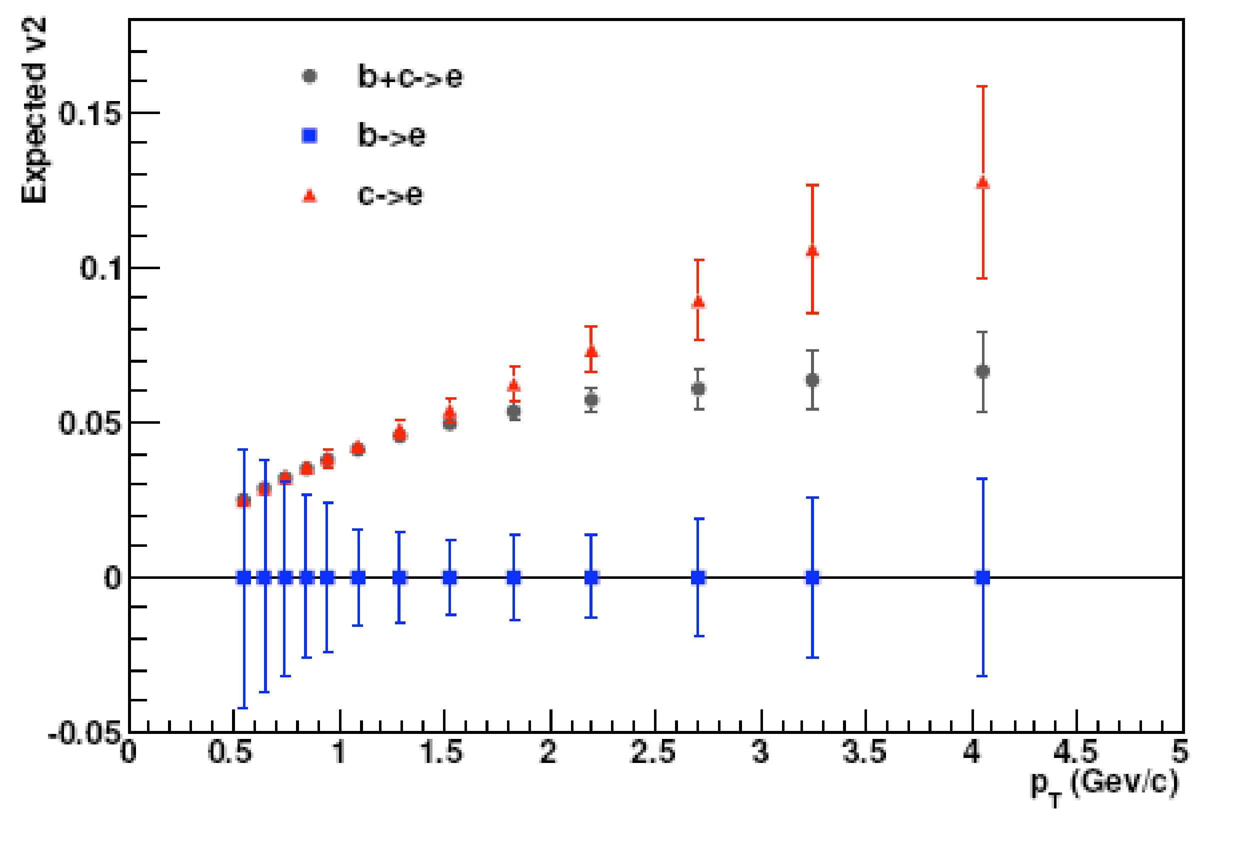
Heavy quark flow in Run-11

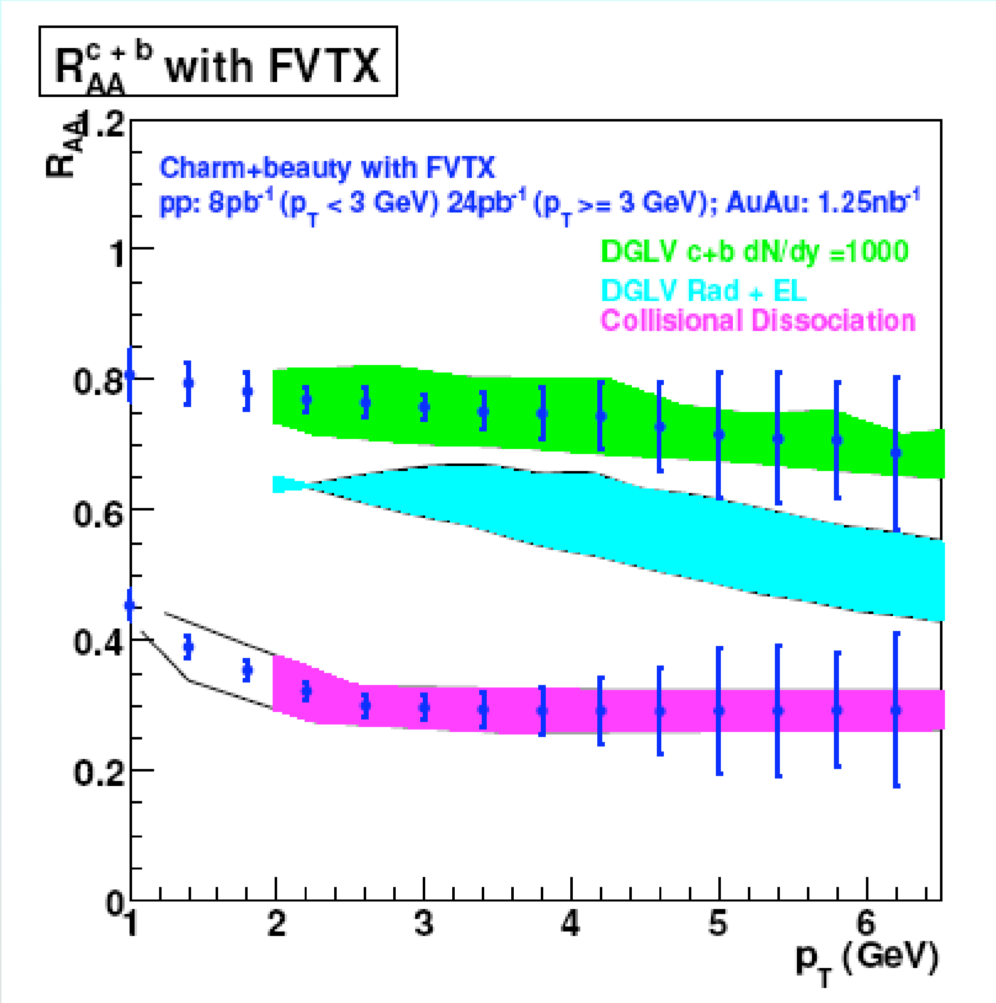


Assumption: Full 8 weeks data taking

NB: simulated limited p_T range.

Good sensitivity for v_2 decrease at high p_T

Run-12 FVTX physics

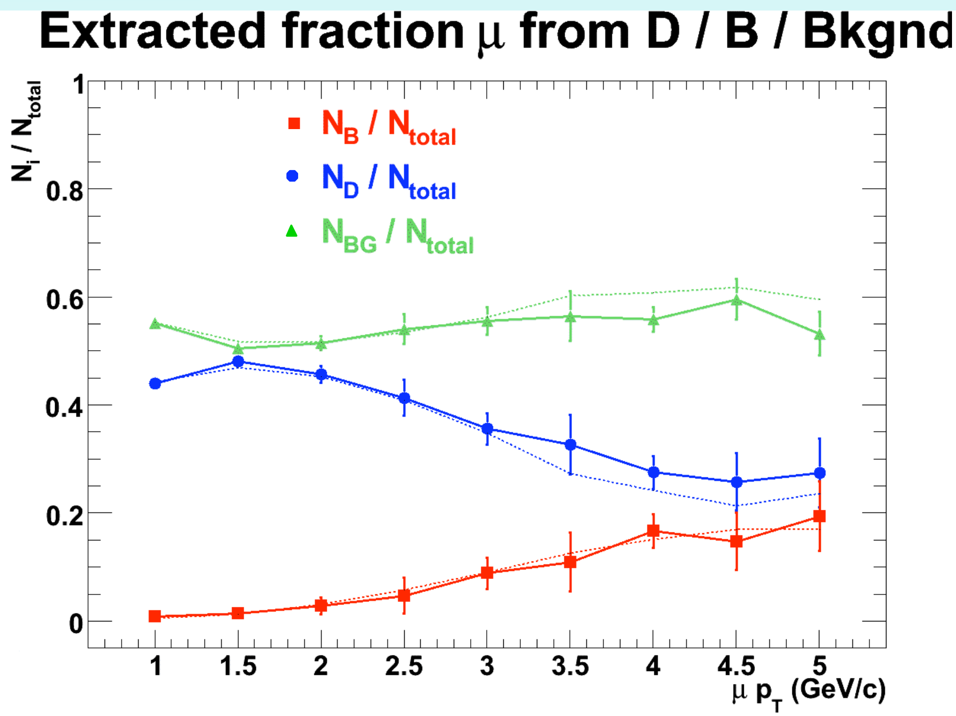


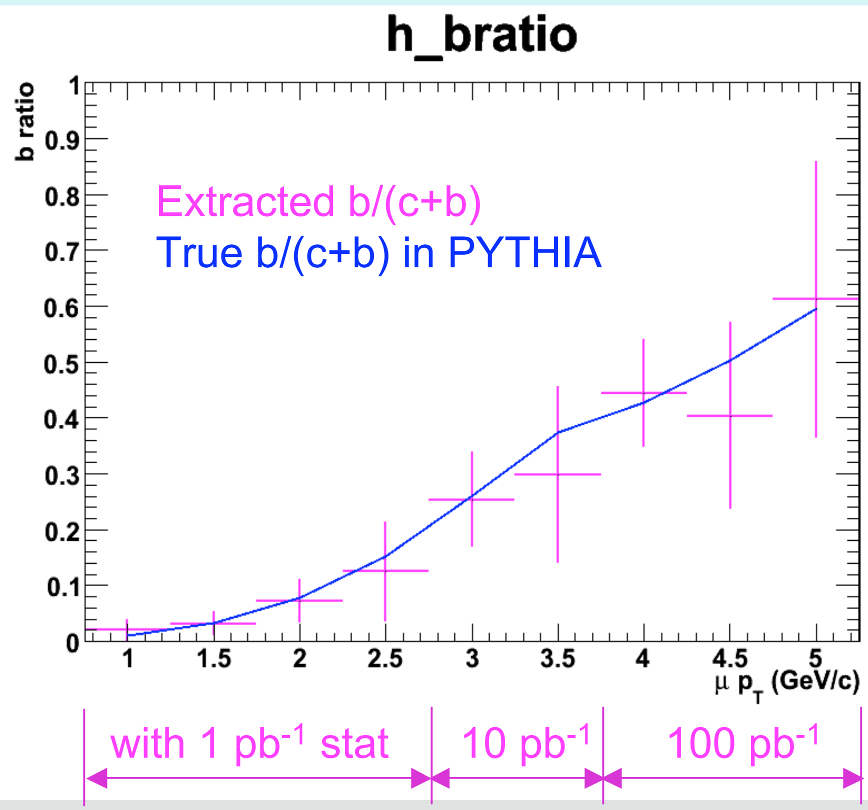
Run-12 Goals:

Commission

Take first part of this data set

Beauty & charm separation at different muon p_T





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Backgrounds at 500 GeV

- Data analysis underway…

- First taste of >1 MHz interaction rates
- Demonstrated operability of detectors
- Multiple collisions per crossing and in adjacent crossings
  - Learned how to deal with it
  - Revised drift chamber calibration approach
- Scaling the backgrounds to the collision rate worked OK as a rule of thumb
- RPCs provided key monitoring instrumentation
  - Probably would like to install additional monitors

PHENIX

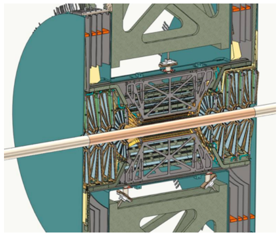
Future HI Milestones

Requires upgrade

Year	#	Milestone
2009	DM4	Perform realistic three-dimensional numerical simulations to describe the medium and the conditions required by the collective flow measured at RHIC.
2010	DM5	Measure the energy and system size dependence of J/Ψ production over the range of ions and energies available at RHIC.
2010	DM6	Measure e^+e^- production in the mass range $500 \leq m_{e+e-} \leq 1000$ MeV/c2 in $\sqrt{s_{NN}} = 200$ GeV collisions.
2010	DM7	Complete realistic calculations of jet production in a high density medium for comparison with experiment.
2012	DM8	Determine gluon densities at low x in cold nuclei via p + Au or d + Au collisions.
2015	DM9 (new)	Measure bulk properties, particle spectra, correlations and fluctuations in Au + Au collisions at $\sqrt{s_{NN}}$ from 5 to 40 GeV to search for evidence of a critical point in the QCD matter phase diagram.
2014	DM10 (new)	Perform calculations including viscous hydrodynamics to quantify, or place an upper limit on, the viscosity of the nearly perfect fluid discovered at RHIC.
2014	DM11 (new)	Measure jet and photon production and their correlations in A≈200 ion+ion collisions at energies from $\sqrt{s_{NN}} = 30$ GeV up to 5.5 TeV.
2016	DM12 (new)	Measure production rates, high pT spectra, and correlations in heavy-ion collisions at $\sqrt{s_{NN}} = 200$ GeV for identified hadrons with heavy flavor valence quarks to constrain the mechanism for parton energy loss in the quark-gluon plasma.
2018	DM13 (new)	Measure real and virtual thermal photon production in p + p, d + Au and Au + Au collisions at energies up to $\sqrt{s_{NN}} = 200$ GeV.

Spin Physics Milestones

Year	#	Milestone
2013	HP8	Measure flavor-identified q and $\bar{q}$ contributions to the spin of the proton via the longitudinal-spin asymmetry of W production.
2013	HP12	Determine if gluons have appreciable polarization over any range of momentum fraction between 1 and 30% of the momentum of a polarized proton.
2015	HP13	Test unique QCD predictions for relations between single-transverse spin phenomena in p-p scattering and those observed in deep-inelastic lepton scattering.



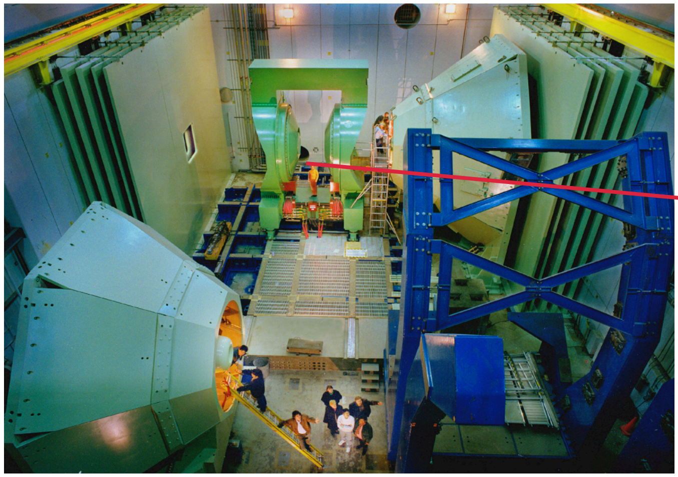
Forward Silicon Vertex Detector (FVTX)

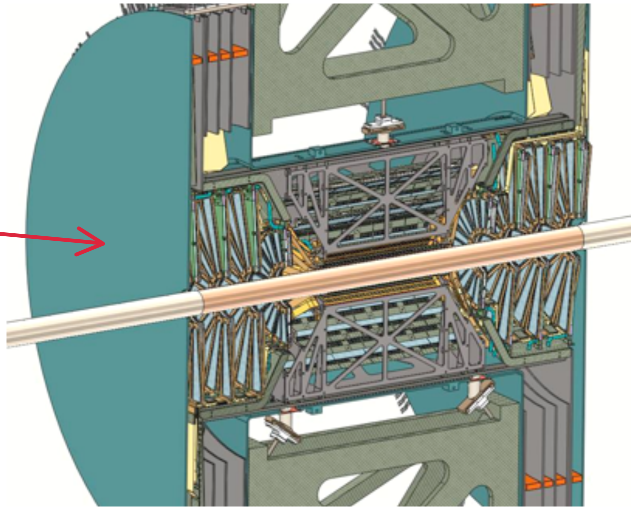
Single Muons:

- Precision heavy flavor and hadron measurements at forward rapidity
- Separation of charm and beauty
- Additional W background rejection

Dimuons:

- First direct bottom measurement via $B \rightarrow J/\psi$
- Separation of J/ψ from ψ' with improved resolution and S:B
- First Drell-Yan measurements from RHIC





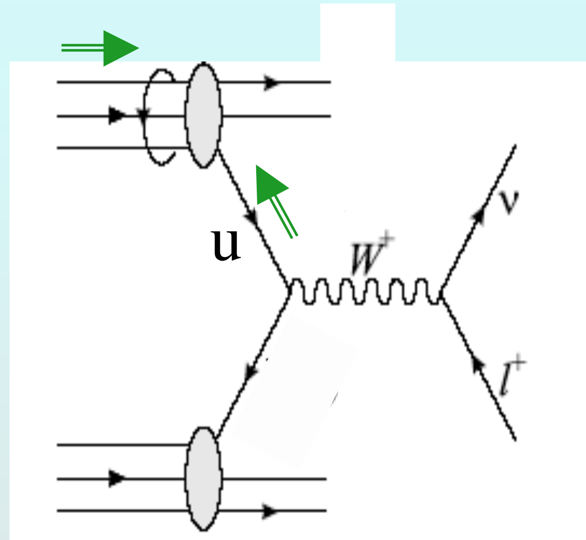
ΔG not large: sea quarks polarized? d vs. u?

Probe $\Delta\bar{q}$-Δq via W production

$$\Delta d + \bar{u} \rightarrow W^-$$
$$\Delta \bar{u} + d \rightarrow W^-$$
$$\Delta \bar{d} + u \rightarrow W^+$$
$$\Delta u + \bar{d} \rightarrow W^+$$

$\vec{p}$

p unpol.

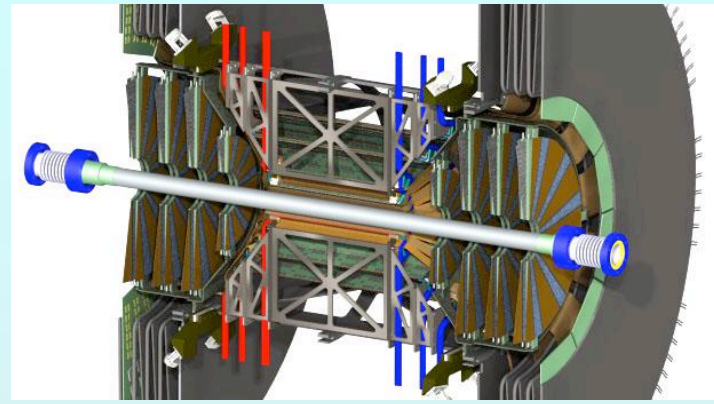


100% Parity-violating: $A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$

Start: 2009(tests)/2010(trigger) with 500 GeV p+p

PHENIX

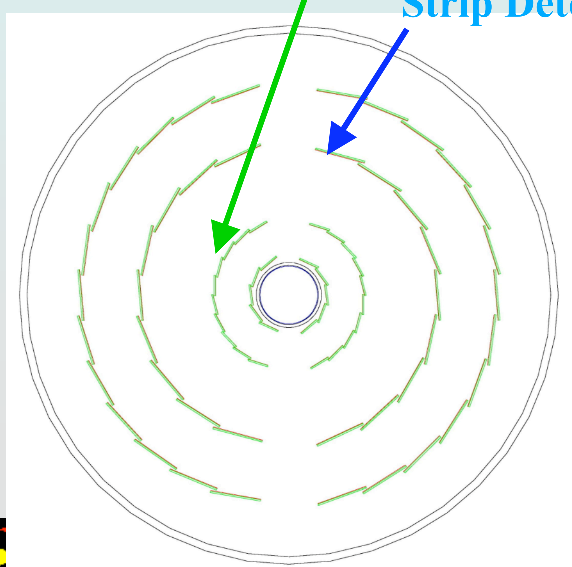
Barrel VTX Detector

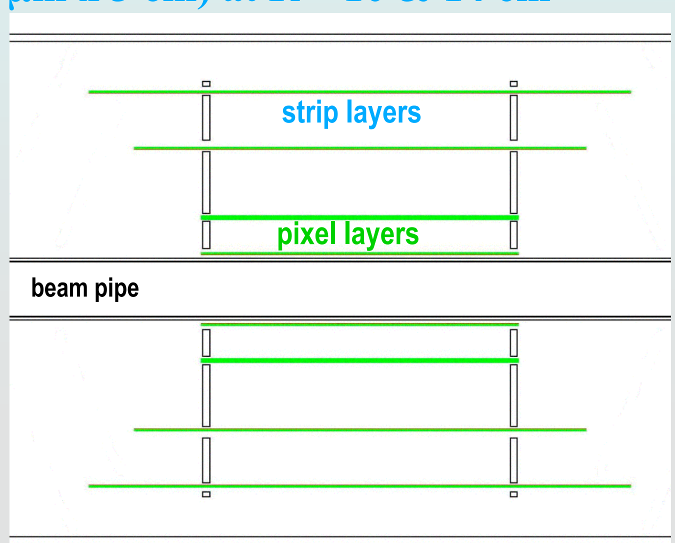


- **Specifications:**
  - **Large acceptance ($\Delta\phi \sim 2\pi$ and $|\eta| < 1.2$)**
  - **Displaced vertex measurement $\sigma < 40$ μm**
  - **Charged particle tracking $\sigma_p/p \sim 5\%$ p at high pT**
  - **Detector must work for both HI and pp collisions.**
- **Technology Choice**
  - **Hybrid pixel detectors developed at CERN for ALICE**
  - **Strip detectors, sensors developed at BNL with FNAL's SVX4 readout chip**

Hybrid Pixel Detectors (50 μm x 425 μm) at R ~ 2.5 & 5 cm

Strip Detectors (80 μm x 3 cm) at R ~ 10 & 14 cm



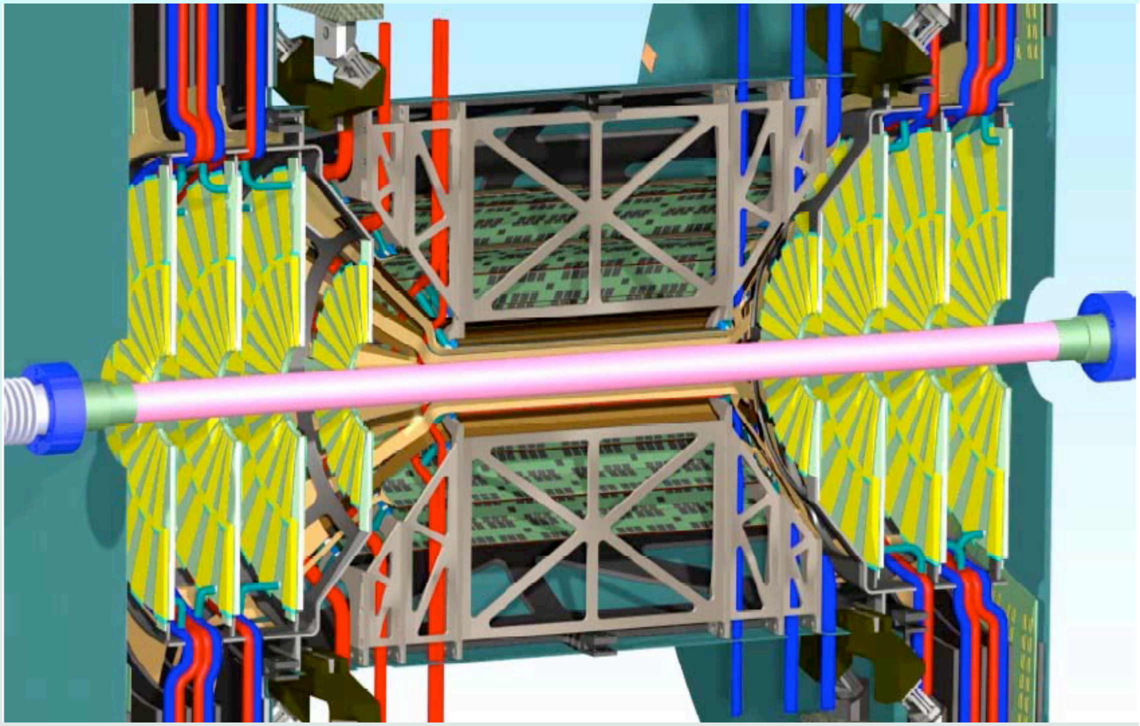


$|\eta|<1.2$
$\phi \sim 2\pi$
$z \sim \pm 10$ cm

Forward Silicon Vertex Detector - FVTX

FVTX Specifications:

- 2 endcaps
- 4 pixelpad layers/endcap
- ~550k channels/endcap
- Electronics a mod of BTeV readout chip
- Fully integrated mech design w/ VTX
- 2π coverage in azimuth and $1.2 < | \eta | < 2.4$
- Better than 100 μm displaced vertex resolution



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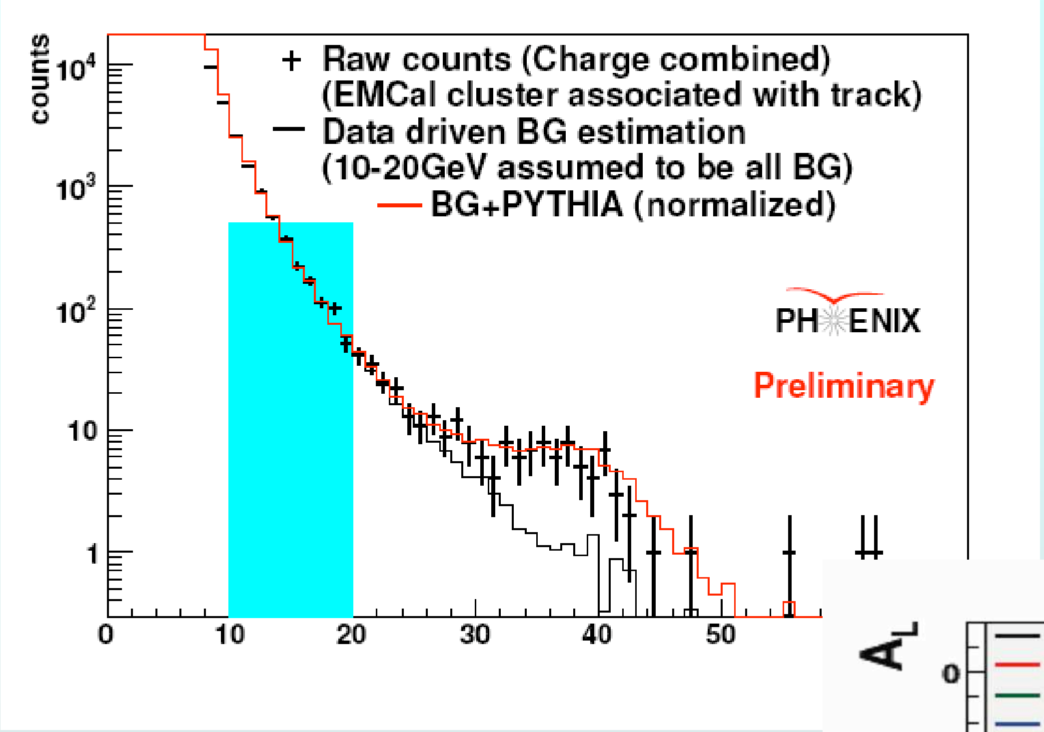
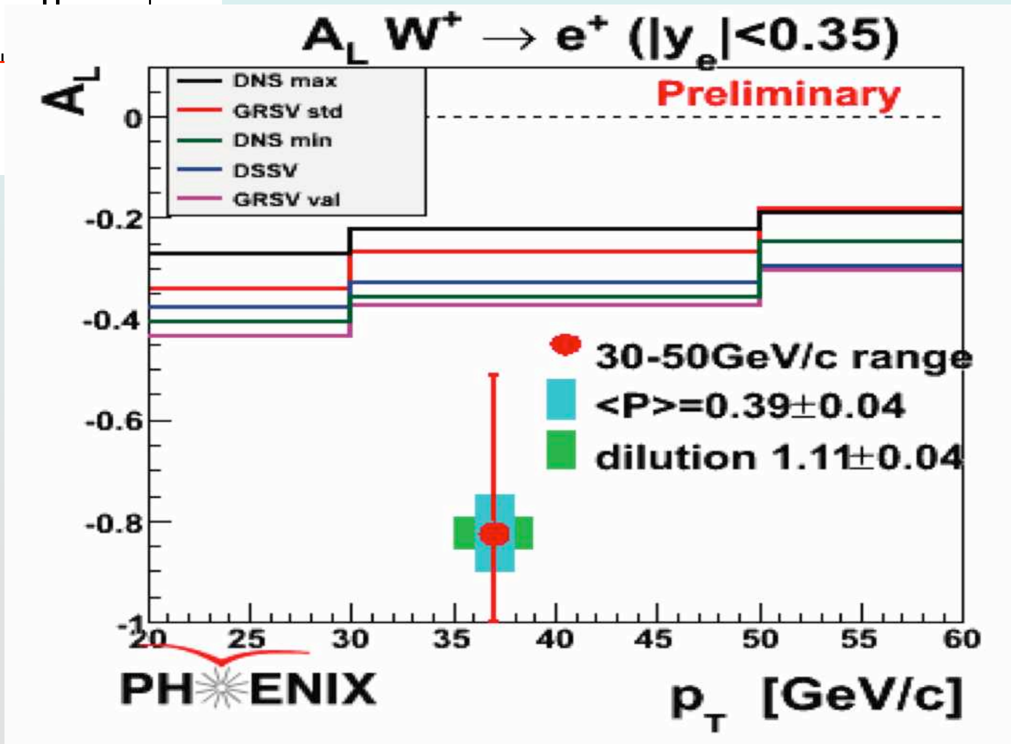
Q.4: W cross section & asymmetry?

Run-9 preliminary





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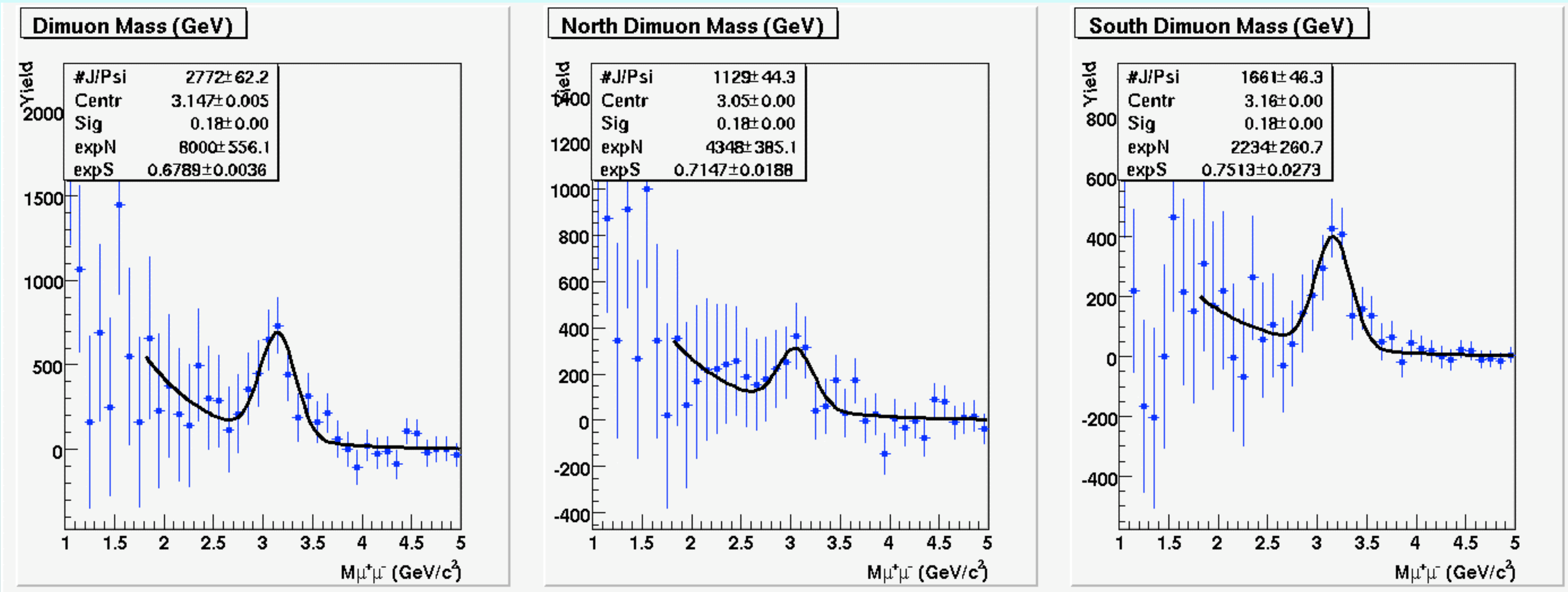
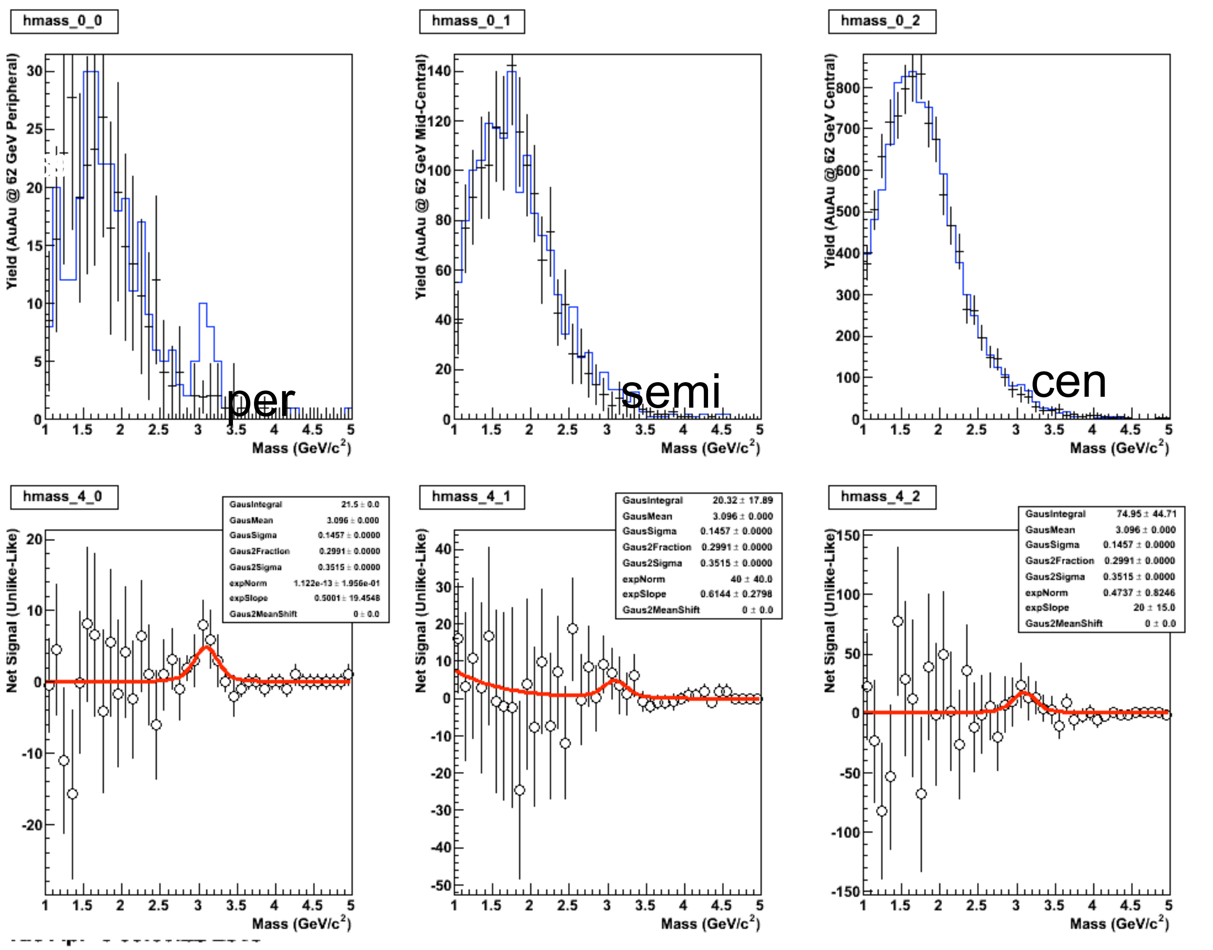
J/ψ in Muon Arms in Run-10 @ 200 GeV



J/ψ yield as expected

Analyzed Luminosity (for mass plots):
147.7 μb^{-1} gives 18.8 +- 0.4 (stat) J/Ψ per μb^{-1}
Compared to Run7 Au+Au which had about 18.2 J/Ψ per μb^{-1}

J/ψ: analyzed 25% of 62 GeV statistics



- **Recombination**
  (e.g. Rapp et al.)
  J/ψ yield at 200 GeV is dominantly from recombination
- **Predict suppression greater at 62 GeV**
  J/ψ yield down by 1/3
  Recombination down 1/10

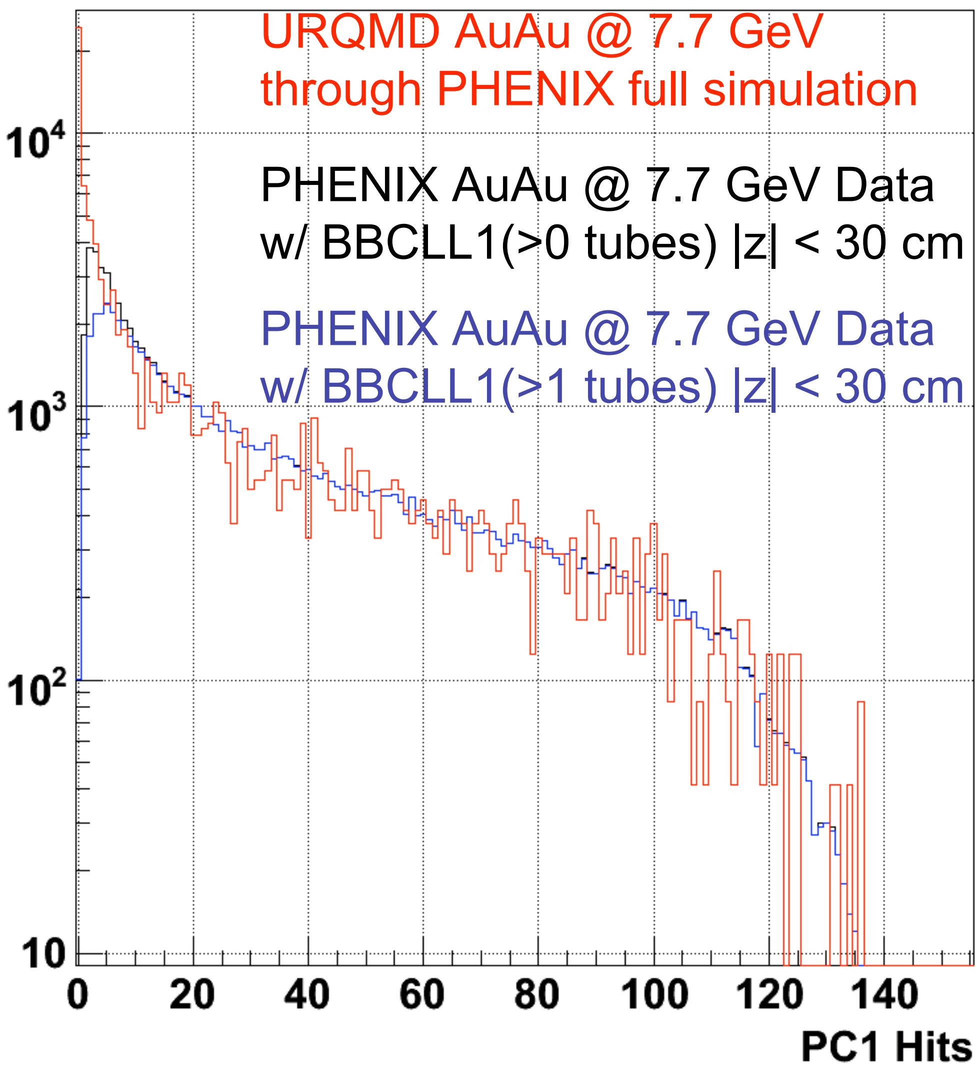
600 M min. bias events → 500 J/ψ ∴ measure J/ψ suppression

Key test of recombination!

Success at 7.7 GeV Au+Au!

The trick?

Tight timing cut on BBC N vs. S!



URQMD normalized to match real data integral for PC1 hits > 40.

URQMD not matched to z distribution in real data. **However, note that there is no rescaling of the x-axis.**

Then comparing the integrals implies (as a first look) that the BBCLL1(>0 tubes) fires on 77% of the cross section and the BBCLL1(> 1 tubes) fires on 70% of the cross section.

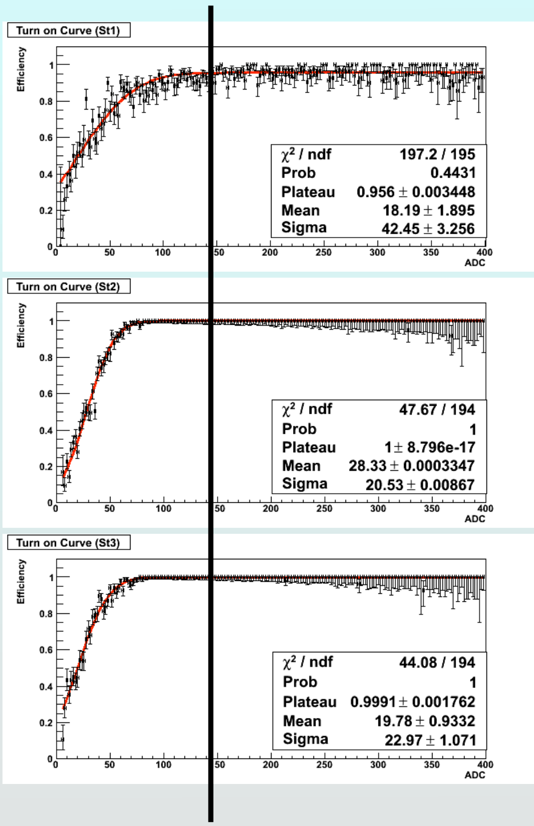
No indication of deviation at low PC1 hits from background (at least by this particular check).

MUTRIG ready for physics in Run-11

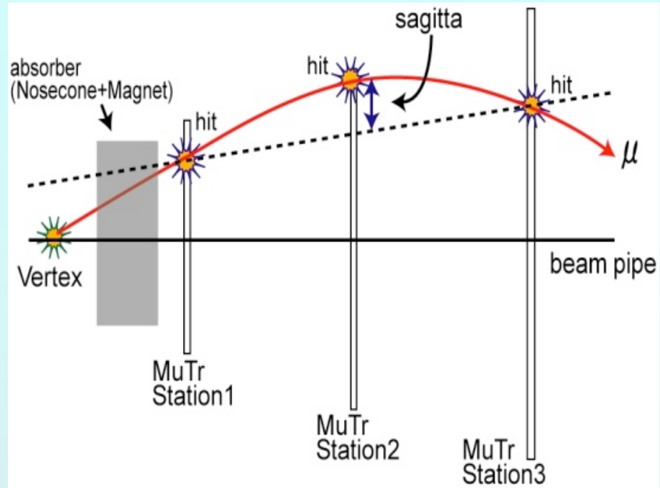
Station 1

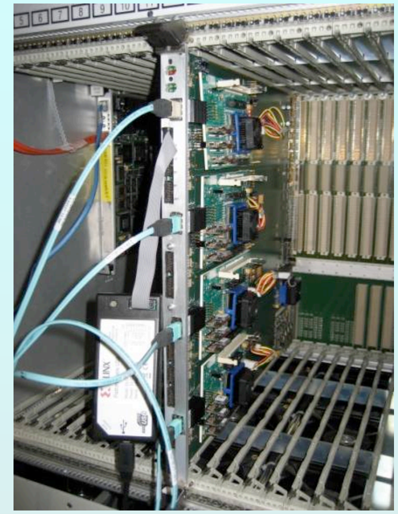
Station 2

Station 3



Minimum Ionizing Particle



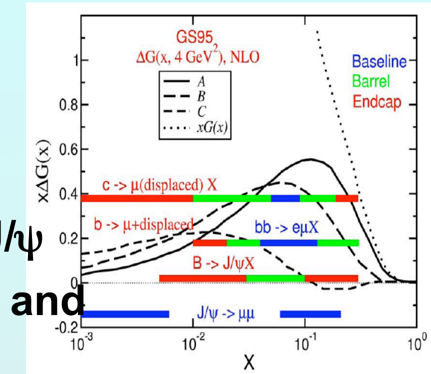


- Good efficiency for MIPs
- MUTR.N installed for Run-9
- MUTR.s installed for Run-10
- ready to go

PHENIX

Forward Silicon Vertex Detector - FVTX

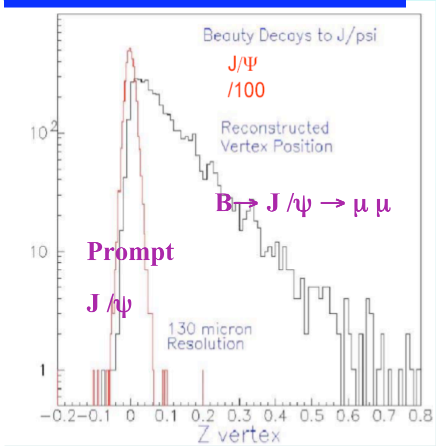
Enhanced x coverage



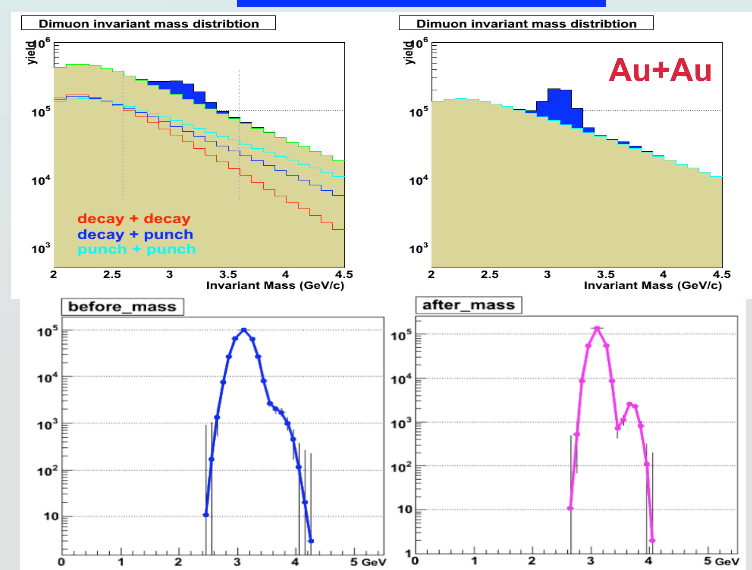
Physics Program of FVTX includes

- Resolving J/ψ and ψ' in Muon arms
- Resolving ϒ at y=0 using Muon arms
- Direct measure of B meson through displaced J/ψ
- Drell-Yan Measurements in dAu at both forward and midrapidities
- c, b ID for both HI physics & ΔG spin measurements
- Nuclear modification factor (CGC effects) in dAu using hadrons, c, b, and J/ψ

Direct measure of B



J/ψ, ψ' separation



c, b suppression at forward η